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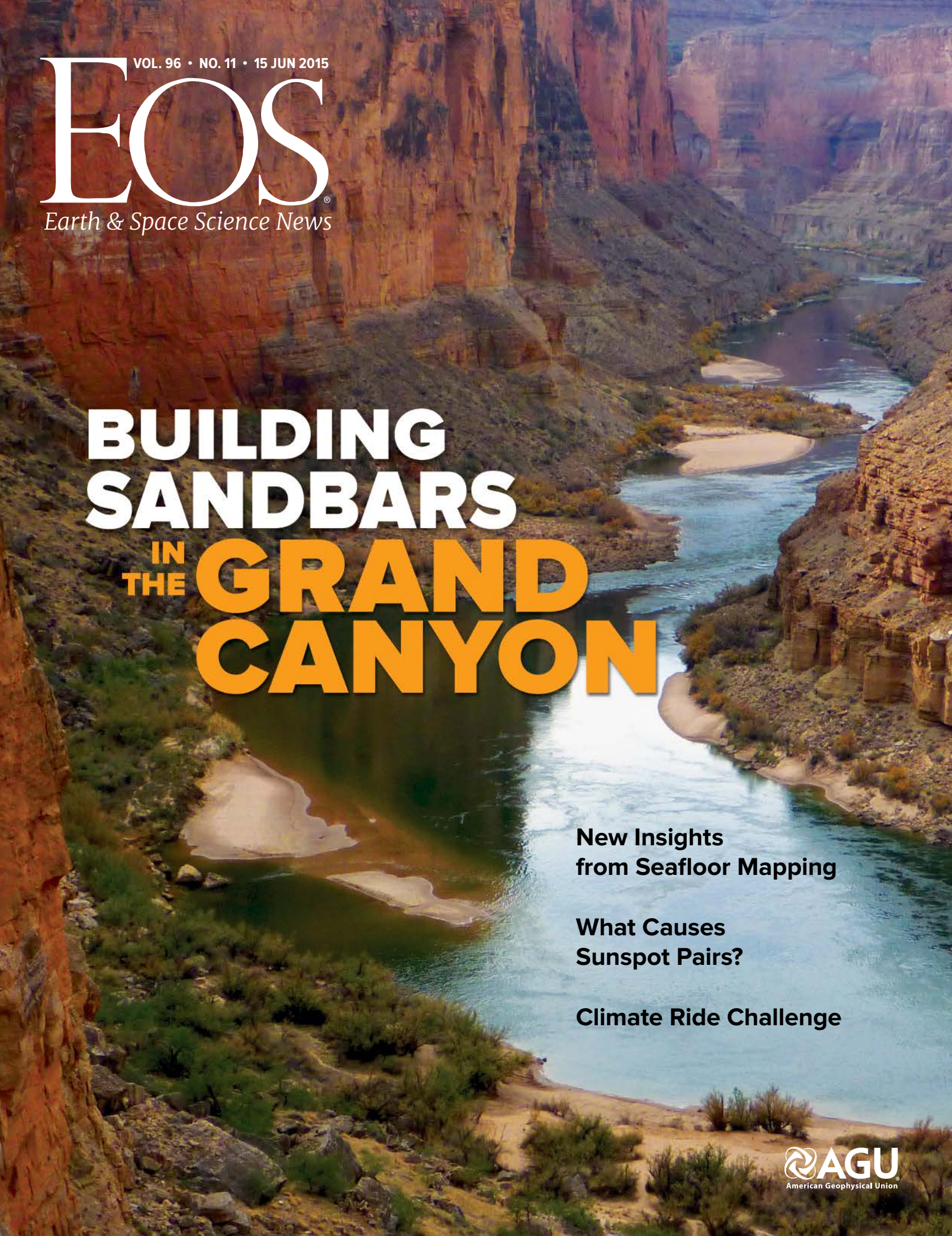
EOS

Earth & Space Science News



BUILDING SANDBARS IN THE GRAND CANYON

New Insights from Seafloor Mapping

What Causes Sunspot Pairs?

Climate Ride Challenge

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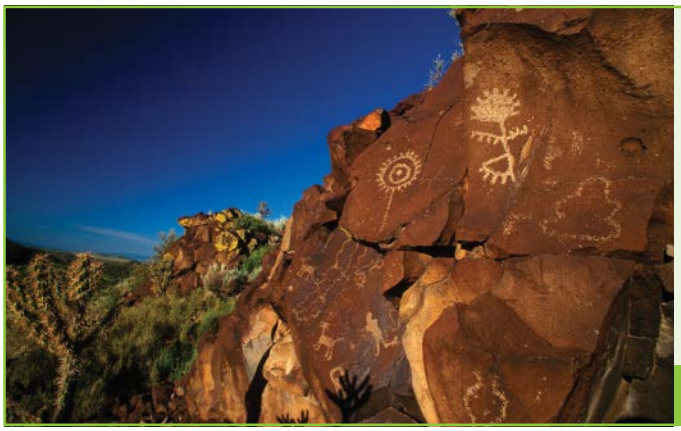

The Width of the Tropics: Climate Variations and Their Impacts

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27–31 July

Registration Deadline: 2 July

Magnetospheric Dynamics

Fairbanks, Alaska, USA
27 September–2 October

Registration Deadline: 24 August

The MADE Challenge for Groundwater Transport in Highly Heterogeneous Aquifers

Valencia, Spain
5–8 October

Abstract Deadline: 17 June

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A detonation of less than 0.03% of the current global nuclear arsenal could cause fires that clog the air with soot. This soot could block solar radiation, leading to worldwide crop shortages.

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Eos

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Warmer Climate Could Aid Quebec's Wine Industry

Wine lovers of the world, prepare: Quebec, Canada, may soon be the newest destination for winery tours.

Although Quebec already hosts a successful—albeit fledgling—wine industry, its bitterly cold winters limit the current grape-growing potential to cold-hardy varieties such as Vidal and Seyval, which are less known than their popular European counterparts like Pinot Noir and Chardonnay.

Thus, some aspects of climate change—notably the warmer temperatures it promises—might herald good news for Quebec's wine industry. In a press conference presented at the 2015 Joint Assembly, a meeting of U.S. and Canadian geoscientist organizations in Montreal, Quebec, climate researchers explained that the province's cold weather and snow, which can damage grapes' blooming buds or kill the vine outright, may be countered by longer, warmer growing seasons.

"With this study we can look at where the next region of wine making could be located," said Philippe Roy, lead researcher and climate scenarios specialist at the Ouranos Consortium on Regional Climatology and Adaptation to Climate Change.

The Climate Models Speak

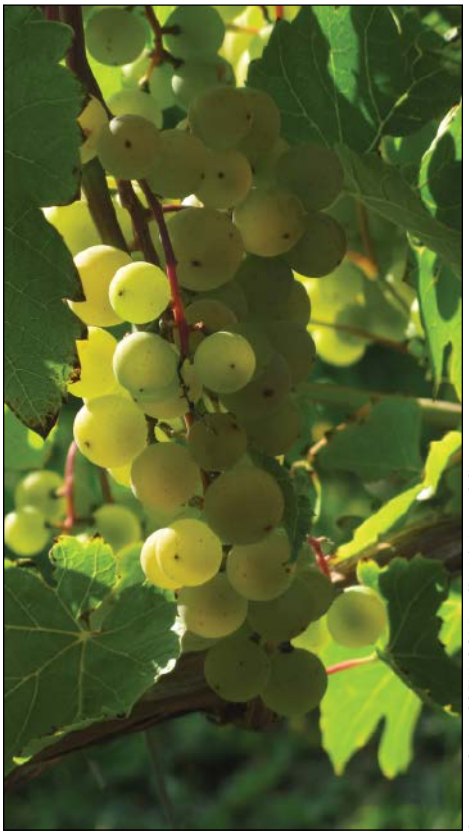
Roy and his colleagues framed their investigation within two of the many factors that lead to a successful harvest: the number of consecutive days without frost and the number of growing degree days (GDDs). The latter tells vintners how many days of the growing cycle reach temperatures conducive for good wine and can fluctuate depending on region and grape variety.

The researchers used climate models to simulate how Quebec's climate would change under two greenhouse gas emission scenarios designed by the Intergovernmental Panel on Climate Change. The first is the "business as usual" scenario, in which greenhouse gas emissions do not decrease in the 21st century. The second is a scenario in which greenhouse gas emissions peak in 2040 then decline.

Within these scenarios, the researchers searched for areas in climate predictions that gave 180 consecutive days without frost, which is the minimum for European varieties such as Pinot Noir, and 900 GDDs, which is also a bare minimum for grape growers. Then they examined what wine-growing conditions would be like in the coming century within Quebec. They found that by 2050, favorable grape-growing conditions are 70%–90% likely to emerge in the province.

> "In terms of climate conditions, we can expect increased wine making potential."

Next, the researchers focused on the region in southern Quebec called Estrie, which borders northern Vermont. By plugging in the required 180 consecutive days without frost and 1250 GDDs needed for European grape varieties, the researchers found a 70% chance of suitable grape-growing conditions emerging by 2050.



Susan van Gelder, CC BY-NC-SA (http://bit.ly/ccbyncsa2-0)

Grapes hanging on a vine in Saint-Joseph-du-Lac, Quebec.

Bottom line: "In terms of climate conditions, we can expect increased wine-making potential" in the southern regions of Quebec, Roy said at the press conference. These regions may be able to grow more varieties of grapes, such as Merlot, Pinot Noir, and Chardonnay, which could make these future wineries' products more desirable to consumers, Roy told *Eos*.

Two Sides of the Same Coin

Although Quebec and other parts of Canada might get a friendlier growing season, vineyards in other parts of the world may not fare as well under a changing climate. Past research has shown that under a business as usual greenhouse gas emissions scenario, places like Australia, Italy, Spain, France, and South Africa would see a sharp decrease in grape-growing productivity—anywhere from 25% to 73%, depending on the region. Some wineries are already moving their production toward the poles, where the heat can be less unrelenting.

Warmer weather may also affect the taste and alcohol content of wine because temperature-induced chemical processes that occur within growing grapes could make them less desirable to consumers.

Although the wine industries in southern Quebec may see a boost, changing climates are already altering other agricultural industries in the province. For example, warmer temperatures have started to threaten maple syrup harvests in southern regions as production creeps northward, toward cooler temperatures.

Hopes for a Growing Industry

"The wine making in Quebec is still at an early stage, but things are looking good on the climate side of the next decades," Roy said.

However, climate change does not just mean warmer weather. It can also influence soil health, the spread of pathogens, and invasive species, said Isabelle Charron, a climate scenarios specialist at Ouranos.

"There are other factors that also have to be considered when you are going to decide whether wine making is going to be possible," Charron said.

By **JoAnna Wendel,** Staff Writer

Bill that Limits Earth Science Funding Wins OK in House

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The House of Representatives approved the America COMPETES Reauthorization Act.

The U.S. House of Representatives approved, on 20 May, the America COMPETES Reauthorization Act (H.R. 1806), which would limit some funding for Earth science research at the National Science Foundation (NSF) and the Department of Energy's Office of Science for fiscal years (FY) 2016 and 2017. The bill also would authorize funding for the National Institute of Standards and Technology, among other measures.

The bill, which would authorize funding but would not appropriate it, would fund the NSF Directorate for Geosciences at $1.2 billion for FY 2016 as well as for FY 2017. This amount falls short of the $1.3 billion FY 2015 estimated budget level and the $1.37 billion administration request for FY 2016.

NSF as a whole would receive $7.6 billion for FY 2016, which is $235 million above FY 2015 but less than the administration's FY 2016 request of $7.72 billion. The legislation would provide specific allocations for NSF directorates. The bill would prioritize funding for NSF's directorates of Biological Sciences, Engineering, Computer and Informational Science, and Mathematical and Physical Sciences. It would also sharply cut funding for the agency's Directorate of Social, Behavioral and Economic Sciences.

Republican supporters of the bill, which passed by a vote of 217–205 with no Democrats voting for it, have called it "a comprehensive, pro-science, fiscally responsible bill to keep America competitive and reestablish the federal government's primary scientific role to fund basic research." However, Democrats say the legislation "embraced a partisan, anti-science agenda."

The bill next will be considered by the Senate. The Senate currently is working on its own versions of the COMPETES Act. An 18 May statement from the White House Office of Management and Budget said that the administration strongly opposes H.R. 1806 and that if the president were presented with it, his senior advisors would recommend that he veto the bill. The bill "undermines key investments in science, technology, and innovation and imposes unnecessary and damaging requirements on Federal support of research," according to the statement.

Appropriations Bill Approved by Committee

Passage of the America COMPETES bill came on the same day that the House Appropriations Committee approved the FY 2016 Commerce, Justice, Science Appropriations bill, which funds the Department of Commerce, the Department of Justice, NASA, NSF, and other related agencies. That bill, which appropriates rather than just authorizes funding, would provide $7.4 billion to NSF, an increase of $50 million above the FY 2015 level and $329 million below the administration's request.

The appropriations bill, which needs to be approved by the full House, includes $6 billion for research and related activities. The bill report language calls for 70% of that $6 billion to go to the NSF directorates for Biological Sciences, Engineering, Computer and Informational Science, and Mathematical and Physical Sciences. This would force NSF to cut more than $250 million from the agency's Directorate for Geosciences and the Directorate for Social, Behavioral and Economic Sciences, according to the Coalition for National Science Funding.

The Debate over America COMPETES

During the debate over H.R. 1806 prior to the vote, members on both sides of the aisle offered sharply different perspectives on the legislation.

Rep. Lamar Smith (R-Tex.), chair of the House Science, Space, and Technology Committee and sponsor of the bill, said, "Our colleagues on the other side of the aisle today would have you believe that the only way to be pro-science is to spend more taxpayer money than the Budget Control Act allows. That is irresponsible. If everything is a priority, then nothing is." He added that the bill maintains funding for NSF "in the hard science areas of geoscience, like deep ocean drilling and geological research to find new energy sources."

"The Obama administration has unapologetically pushed forward a politicized climate agenda through the federal government, prioritizing climate change research above all else," Rep. Bruce Westerman (R-Ark.) said. The bill "gives Congress appropriate oversight to fund valuable research but does not provide a blank check for the president's climate agenda."

Meanwhile, Rep. Katherine Clark (D-Mass.) defended funding for the geosciences, saying it is critical for work related to disaster resilience, drought, solar storms, ocean health, agriculture, and climate change. "Climate change is real, human activity contributes to it, and it is bad for the bottom line," she said. "It is irresponsible for us to cut funding for research that helps us understand what is happening and how to address it. Adequately funding geoscience research is critical to protecting and growing our economy and to the security of the American people."

Rep. Suzanne Bonamici (D-Oreg.) expressed concern about reduced authorized funding levels for specific directorates, including the geosciences. She said that setting authorization levels according to directorate would limit NSF's needed flexibility to set strategic priorities and adapt and capitalize on unanticipated discoveries. Bonamici said the bill "diminishes the ability of [NSF] to make strategic science-based decisions."

By **Randy Showstack,** Staff Writer

Geoscience Community Reacts to Vote on America COMPETES Bill

Members of the geoscience community have generally reacted unfavorably to the U.S. House of Representatives' 20 May passage of the America COMPETES Reauthorization Act (H.R. 1806).

The bill, which would limit the authorization of Earth science funding for the National Science Foundation's (NSF) Directorate for Geosciences and for the Department of Energy's (DOE) Office of Science, has been labeled by Republican supporters as responsible budgeting and pro-science. Democrats and many geoscience organizations have decried the legislation as anti-science.

On the same day that the House okayed the COMPETES Act, the House Committee on Appropriations approved the fiscal year (FY) 2016 Commerce, Justice, Science (CJS), and Related Agencies Appropriations bill, which would also restrict the appropriation of some funding for the geosciences at NSF, among other measures.

Community Concerns About the Bill

Thomas Bogdan, president of the University Corporation for Atmospheric Research, told *Eos*, "Geoscience programs such as improved weather forecasts and better understanding of natural hazards have contributed substantially to economic growth in the United States, and they need ongoing and consistent support to keep fueling the nation's economy. As the bill moves to the Senate, I hope we can address and improve the legislation so it better ensures the stability of funding for the geosciences."

Erin Heath, associate director of government relations with the American Association for the Advancement of Science (AAAS), stated, "Two years ago, AAAS joined a broad coalition of scientific and engineering societies, higher education institutions, and private sector businesses in endorsing a set of Guiding Principles for the America COMPETES Reauthorization Act. The principles advocated for steady and sustained real growth in funding for major federal research agencies and to maintain a strong foundation of fundamental research across all scientific disciplines. AAAS is concerned that the House bill falls short of these goals."

"We are concerned about efforts to, in effect, place certain NSF research directorates over others," Heath continued. "To highlight just one example of important geoscience and social science research, the AAAS Geospatial Technologies Project analyzes data using geographic technologies such as remote sensing, geographic information systems (GIS), and global positioning systems (GPS). This data can provide critical information on the impact of remote, isolated conflicts on civilians; a host of human rights violations; damage to sites of cultural heritage; environmental and social justice issues; cross-border conflicts; and indigenous rights."

"An Alarming Trend"

Barry Toiv, vice president for public affairs with the Association of American Universities, told *Eos*, "When you consider the COMPETES legislation and the CJS bill passed by the House Appropriations Committee [on 20 May], you see an alarming trend of Congress favoring some areas of science at the expense of others. This would shortchange critical research in such areas as geological and environmental science as well as the social sciences, such as economics and psychology. The fundamental problem here is that Congress needs to allocate more funds for domestic programs. This will make available the resources needed to fund all areas of science in a way that prevents an innovation deficit vis a vis other countries and maximizes the benefits of research to our economy, our health, and our national security." He added, "These bills are clear examples of why Congress needs to act this year on the larger budget issues that are harming our national interest."

> "We would not concede our military superiority to China or Russia; why would we concede our scientific superiority?"

A few days prior to the vote, Sherri Goodman, president and CEO of the Consortium for Ocean Leadership, told *Eos*, "We would not concede our military superiority to China or Russia; why would we concede our scientific superiority? That's what the America COMPETES Act proposes in cutting investment in NSF geosciences, whose funding supports the scientific and technology investment our nation needs for oil and gas development, among other workforce needs."

Pressure on Department of Energy Funding

Kateri Callahan, president of the Alliance to Save Energy, addressed concerns related to funding for the DOE, telling *Eos* that "H.R. 1806 would have a devastating impact on federal funding of research and development [R&D] of energy efficiency technologies, and represents a huge setback for energy efficiency in America. The bill cuts funding for Energy Efficiency and Renewable Energy (EERE) R&D by 29% below FY 2015 appropriated levels, and 50% below the president's FY 2016 request. It would also cut funding for ARPA-E [Advanced Research Projects Agency – Energy] by 50%. Other provisions in the bill will block the pursuit of the type of high-risk, high-reward, breakthrough research that ARPA-E was created to support and that is important for American economic competitiveness."

She added, "Energy efficiency has served for nearly four decades and remains today America's cheapest, cleanest, and most abundant resource. The energy productivity has doubled over the past three decades. These economic productivity improvements over this period have reduced our national energy bill by about $700 billion. These economy-wide benefits would not have been possible without federal funding of R&D into energy efficiency technologies and practices. Energy efficiency R&D is vitally important to developing and deploying this abundant and cost-effective resource. And the type of R&D supported by ARPA-E is critical for developing breakthrough technologies that will propel [the United States] closer to a leading position in the world as a developer of energy efficiency technologies." Callahan continued, "H.R. 1806 would reverse the progress we have made in the past 30 years and make it even harder for the United States to compete in technology development in the world marketplace. We strongly oppose H.R. 1806 and will be actively urging the Senate [to] move a very different authorization bill for America COMPETES as this legislation moves forward."

However, Myron Ebell, director of the Center for Energy and Environment at the Competitive Enterprise Institute, which advances the principles of limited government, spoke favorably about the COMPETES Act. He told *Eos* that the House's passage of the act "is a strong step toward reducing federal funding for global warming alarmists, green energy boondoggles, and crony capitalists. If enacted, the bill would also require some accountability from universities that receive grants from [NSF]. If major research universities object to being held accountable for how they spend taxpayer dollars, they should simply stop begging for federal funding."

By **Randy Showstack,** Staff Writer

Tracking the Missing Heat from the Global Warming Hiatus

At the end of the 20th century, climate scientists noticed what they thought at first was an anomaly: a slowdown in the pace of global warming in the lower atmosphere. Today it is a recognized trend that has lasted more than 15 years. Perplexed, oceanographers are on a hunt to find where this missing heat has gone.

As reported in *Nature Geoscience* (see http://bit.ly/LeeEtAl) on 18 May, University of Miami physical oceanographer Sang-Ki Lee and colleagues may have found some of this missing heat: The Pacific Ocean is keeping its cool by sending heat over to the Indian Ocean. This heat redistribution, the researchers say, could play a role in regulating the rate of global warming.

Oceans: A Complex Buffer

Why the global warming hiatus has happened and how long it will last are mysteries. However, scientists do know that the ocean has recently helped to buffer what was otherwise an accelerated surface warming, one that has not yet stopped. Warming in the upper atmosphere continues to show that the planet is undergoing a radiation imbalance.

However, rather than showing any signs of storing heat, as is the case in the Atlantic Ocean, the Pacific Ocean has actually cooled over the past decade.

"When I noticed from the hydrographic data that the Pacific Ocean heat content has been decreasing since 2003 or so, I was very surprised and puzzled," Lee told *Eos*. "And when I found a large heat increase in the Indian Ocean, I was almost convinced that there was something wrong with the hydrographic data."

How Does Heat Escape to the Indian Ocean?

Lee ran a computer model simulation and found that he could explain the difference if a massive amount of heat from the Pacific flowed through Indonesia's archipelago into the Indian Ocean. However, how best to explain how the heat moves?

Warm water, like warm air, rises—or, rather, stays at the surface when nothing else is disturbing it. This is why, in a lake, the upper layer is warmer than the bottom layer.

To get warm surface water from the Pacific to the Indian Ocean requires wind—and not just any wind. The trade winds need to be strong enough to push water from the eastern Pacific all the way across the ocean basin to the west, where it piles up and creates a region of above-average sea surface height.

Warm surface water can then flow like a river down around the Indonesian archipelago to the Indian Ocean. A difference in height of less than a dozen centimeters is enough to get the heat moving.

The Role of La Niña

Often, the trade winds over the Pacific come up against westerly winds from over the Indian Ocean. During El Niño events, these westerly winds are stronger than the trade winds, and the two will converge in the middle of the Pacific. However, during La Niña events, the westerly winds are extremely weak, and the result is a lower than average sea surface height in the Indian Ocean.

When Lee and his colleagues looked at the temperature observations between the Pacific and Indian Oceans, warming episodes in the latter matched the pattern of the more frequent La Niña events that have occurred over the years.

"We were all very excited to find a good match between the model simulation and the direct measurements," Lee said.

The observations show that "ocean heat transport plays a vital role in redistributing the global energy imbalance," he added.

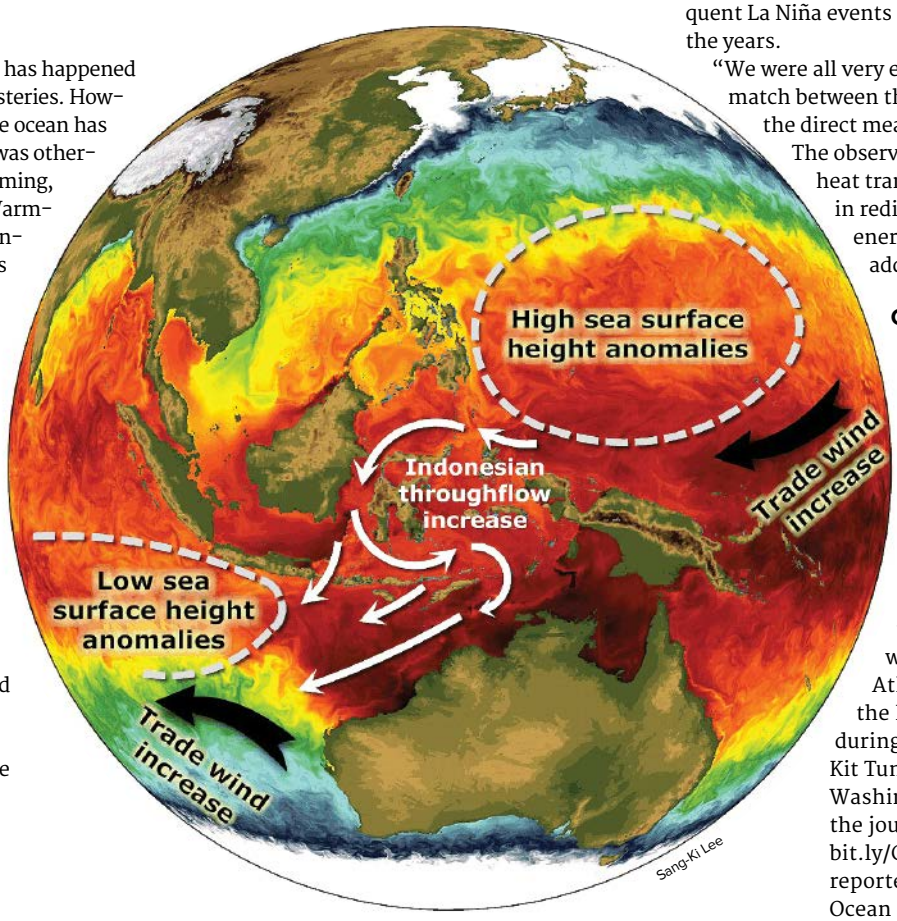


Illustration of increased trade winds in the Pacific and Indian Oceans during the recent warming hiatus, which enhanced the flow of ocean water through the Indonesian archipelago. This resulted in an abrupt increase of Indian Ocean heat content.

Can the Indian Ocean House All of this Hidden Heat?

Lee admits his work is looking at only part of the puzzle—that of the surface heat transport to the Indian Ocean.

Last year, other oceanographers put the focus on deeper water layers in the Atlantic Ocean, dismissing the Indian Ocean's role during this hiatus period. Ka Kit Tung of the University of Washington told *Eos* that in the journal *Science* (see http://bit.ly/ChenEtAl) "we reported…that the Indian Ocean is the only ocean that warmed at the surface and in its upper layers, but it is a minor player in terms of the heat uptake that is needed."

The upper 700 meters of the heat content increase in the Indian Ocean, and, for that matter, in the global ocean, is not enough to explain the near-zero trends in the surface temperature and upper 200 meters' ocean heat content. The key is the heat storage between 200 and 1500 meters of the oceans, which is about 70 zettajoules during the hiatus period," Tung explained. For comparison, the global energy consumption per year is 0.5 zettajoule.

The paper by Lee and his team is "a useful contribution concerning the recent cause of the warming in the upper 700 meters of the Indian Ocean," Tung added.

> "Ocean heat transport plays a vital role in redistributing the global energy imbalance."

"It is not a budget calculation," he explained. "There is a difference between finding some warming in the Indian Ocean and justifying the proposition that the amount of heat storage explains what is needed to account for the global hiatus. [We] not only calculated the heat storage in the Indian Ocean in the upper 700 meters but…calculated it down to 1500 meters and showed that it was not enough."

An Important Piece of the Puzzle

Despite heat budget complexities, some oceanographers find the new results intriguing.

"The report finds that the interbasin heat transport carried by ocean currents may hold the key to deciphering the unsolved missing heat," said Lisan Yu of the Woods Hole Oceanographic Institution.

"Although the study did not explain what drives La Niña conditions in the tropical Pacific, it identifies a potentially important pathway of heat redistribution and provides valuable insight [into] the role of ocean currents in the global warming hiatus," she explained. "The study adds further evidence that the oceans are key to explaining the climate anomalies."

For Jérôme Vialard of the Laboratoire d'Océanographie et du Climat: Expérimentations et Approches Numériques (LOCEAN) in Paris, France, the search for the missing heat is the first step in addressing a broader issue. "The key question is now to understand if this heat will soon be released back to the atmosphere," he said. In such a case, "the 'hiatus' of the last 10 years will be compensated by accelerated surface global warming over the next decade."

By **Christina Reed,** Freelance Writer

National Science Foundation to Rebalance Ocean Science Funding

The National Science Foundation (NSF) plans to cut back on escalating ocean research infrastructure costs and shift that funding to core research and technology programs, the agency announced on 11 May.

The move is NSF's response to a 23 January report by the U.S. National Research Council (NRC) that recommended a major course correction to adjust an imbalance in funding. The agency has endorsed most of the report's recommendations, including reducing NSF funding for the Ocean Observatories Initiative (OOI), the International Ocean Discovery Program (IODP), and the academic research fleet and reallocating that funding to core research and technology programs.

Milan Boers, CC BY 2.0 (http://bit.ly/ccby2-0)

A view of the Atlantic Ocean. The National Science Foundation has endorsed a report calling for a rebalance of its ocean sciences budget.

The NRC report, *Sea Change: 2015–2025 Decadal Survey of Ocean Sciences*, states that the budget for the Division of Ocean Sciences (OCE) within NSF's Directorate for Geosciences "has drifted out of balance" because of relatively flat budgets, inflation, and increasing costs of operations and maintenance for OCE major infrastructure (see http://bit.ly/dsos2015). Funding for OCE core research programs amounted to 62% of division funding in 2000 but just 46% in 2014, according to the report. OCE is the principal U.S. federal agency for funding basic research in the ocean sciences.

Budgetary Realignment

NSF's reply states, "The budgetary realignment between infrastructure and core science and technology is intended to reverse the decline in the proportion of OCE's budget devoted to supporting PI [principal investigator]–driven research proposals. In support of the *Sea Change* recommendations, NSF will reverse this decline by allocating the monies resulting from the decrease in infrastructure operation and maintenance spending to the core programs for research and technology."

The reply continues, "Increased support will be provided to general core science and technology funding, as well as for new initiatives within core programs." However, the agency recognizes that cuts in infrastructure will "present difficult choices and will affect our ability to achieve OCE's research mission," according to the reply.

Restoring Core Science and Technology Grants

OCE director Rick Murray told *Eos* that *Sea Change* "provides an excellent path forward not only in specifics but in how we think about infrastructure in science. We understand how infrastructure and science mutually support each other and broadly agree that the science support was declining to unacceptable levels. [We] think this path forward is worth pursuing. It should result in the needed restoration of core science and technology grants."

He said that NSF's reply to the NRC report "essentially will be a touchstone for us, and I hope the community, as we move forward."

Reduced Funding for Infrastructure

Among the NRC recommendations that the agency endorses is reducing funding for OOI, which is under construction with a transition to operations this summer. NSF will transfer $2 million in OOI operations funding to core research and technology programs. NRC had recommended "initially and immediately" reducing OOI by 20%; however, NSF plans to reduce funding by close to 20% only after a current OOI cooperative agreement with the agency expires in 2017.

The delayed reduction "is seen as a better alternative to the 'immediate' reduction pro-

> "It's going to be tough, but the alternative is that unless this [funding] trend was stopped and reversed, there would ultimately be basically no money for ocean science."

posed by *Sea Change*. Allowing OOI to be fully functional will provide critical information for potential proposers to assess and chart the future directions of the facility," the NSF reply continues.

NSF endorsed the *Sea Change* recommendation to reduce operating costs for the academic research fleet by 5% and for IODP by 10%. "*Sea Change* accurately identifies a fundamental financial imbalance between the U.S. contribution and contributions by IODP's international partners," NSF's reply states.

Among the recommendations endorsed, NSF aims to establish periodic infrastructure reviews. The agency also agreed with a set of priority science questions in the report. "We will continue to support excellent oceanographic science in other areas as well," Murray told *Eos*. He added that NSF would continue to fine-tune, adapt, and implement its response to the report.

Tough Options

Dave Titley, cochair of the NRC committee that produced *Sea Change* and a professor at Pennsylvania State University, told *Eos* that "the ocean science enterprise is the winner" in NSF's plan but that it would be painful for those involved with infrastructure. "It's going to be tough, but the alternative is that unless this [funding] trend was stopped and reversed, there would ultimately be basically no money for ocean science," he said. "Over time, we would frankly lose the intellectual brain power which is really the core of what the ocean enterprise is."

James Yoder, a member of the committee that produced the report and a former OCE division director, told *Eos* that NSF's response "provides a huge boost to the morale of ocean scientists who are struggling to secure proposal funding from the Division of Ocean Sciences. It won't be easy to implement the changes [NSF] describes, although [the agency] has chosen the right path and deserves our full support."

Concerns About Infrastructure Cuts

OOI Program Advisory Committee chairman William Boicourt explained to *Eos* that scientists may not be fully aware of OOI's potential because "community engagement was an insufficient priority during the intense focus required for the project's construction phase."

He said, "If we are to look for good news in this bleak outlook, it is that the Foundation has phased the cuts for OOI and, above all, looked to the community to help make the choices." Boicourt added that some decisions about what to cut are likely to be "Solomon's choices" and that "the procedures for making them are somewhat vague at this point."

Bradford Clement, director of the *JOIDES Resolution* Science Operator for IODP, which operates the *JOIDES Resolution* scientific drillship on behalf of NSF, told *Eos* that he was pleased that NSF recognized efforts the science operator already has made to cut costs while maintaining high levels of performance.

A Measured Response

NSF's reply was "measured and thoughtful," according to Susan Avery, president and director of the Woods Hole Oceanographic Institution, which is involved with OOI and many other infrastructure and science-driven programs. "These are difficult decisions at a time when new infrastructure developed under the understanding of larger NSF budgets is ready for deployment. This new infrastructure will enable new science, but under a flat budget assumption a rebalancing between infrastructure costs and supported science is needed."

However, "given the uncertainty of this budget assumption based on recent Congressional bills, I am concerned that further cuts in NSF's ocean science portfolio will make this rebalancing even more challenging," Avery said. She urged a reassessment of OOI cuts after the initiative is fully formed and the science community recognizes its potential.

Sherri Goodman, president and CEO of the Consortium for Ocean Leadership (COL), expressed support for OOI, which is managed out of COL, and the need for a robust ocean science program. "We support the effort to equitably balance the research and infrastructure portfolio to ensure that the community continues to have access to the sea and adequate resources to provide competitive funding for critical ocean science," she told *Eos*. "These are a series of hard choices, no doubt. But they are not unreasonable, given the options."

By **Randy Showstack,** Staff Writer

Musical Composition Conveys Climate Change Data

Ensia, University of Minnesota

A string quartet from the University of Minnesota's School of Music that performed "Planetary Bands, Warming World" to convey how climate in the Northern Hemisphere has changed over time.

Using a cello, a viola, and two violins, four musicians play the music of climate change through time.

University of Minnesota undergraduate student Daniel Crawford invited these musicians to play his composition entitled "Planetary Bands, Warming World." Each performer represents one of four zones in the Northern Hemisphere: near the equator (cello), the midlatitudes (viola), the upper latitudes (violin), and the Arctic (violin). High notes correspond to high temperatures and vice versa.

Crawford hopes that the music will foster an understanding of climate change where graphs and charts might fail.

Translating Climate Change into Music

To get the range of musical notes, Crawford turned to a data set created by the NASA Goddard Institute for Space Studies of average temperature changes in the Arctic since 1880, the year when temperature observations started to be reliably gathered. He then translated the pitch range of a violin to the range of temperatures seen in the Arctic over the past 135 years.

To match musical notes to temperature, Crawford mapped the lowest annual temperature recorded in the Arctic since 1880 to the lowest note a violin can play and the highest annual temperature to around the highest note a violin can play. Given those bounds, he then calculated the exact pitch corresponding to different temperatures in the data set.

Because Arctic temperatures shift the most rapidly, Crawford used the relative temperature change represented between, say, an A and a B on the musical scale as a baseline shift between pitches for all the other instruments. Then, using similar data from NASA for the other zones in the Northern Hemisphere, he created his musical score. Thus, each shift in pitch for all four instruments represents the same shift in temperature in the data set.

As time progresses in the climate change data set, so too does time progress in the song. As temperatures in the data set rise or fall, each instrument's pitch follows along. By the last few measures of the piece, each instrument's pitch rises considerably, conveying an average rise in temperature across the Northern Hemisphere.

This composition is Crawford's second musical endeavor in climate change communication. In his first, he used his own cello and a set of global average temperatures from 1880 to 2012. This time, Crawford wanted to zoom into a particular region to illustrate how dramatically temperatures have changed across latitudes.

Music and Emotion

Using music to convey the temperature changes in the past century "can elicit a more visceral response," Crawford said. "It can hit people on an emotional level."

Triggering an emotional response is the key to inciting action, said Sabine Marx, managing director of Columbia University's Center for Research on Environmental Decisions, who was not involved in the project.

> "Music is something we experience as almost having a movement quality to it. It actually allows us to use sound to explore concepts of space and time."

Climate scientists face a unique communication problem—they must convince audiences that action is required immediately, even though many people may think of climate change as a future problem. To spur action, or even just a reaction, scientists must tap into the general public's emotional core, Marx said.

Elicited responses can vary. "It could be a very subtle whisper of an emotion or it can be a very vicarious response," she continued. However, she explained, "if there is no emotional response, the willingness to take action is very low."

Music has often been associated with emotional reactions. Numerous studies demonstrate that all types of music can elicit an acute emotional response in the listener, whether it's Mozart or Metallica.

For a complex issue like climate change, which happens over vast periods of time, music could be an effective way to help people understand, said Steven Morrison, director of the Laboratory for Music Cognition, Culture and Learning at the University of Washington, who also was not involved in the project.

"Music is something we experience as almost having a movement quality to it," Morrison said. "It actually allows us to use sound to explore concepts of space and time."

Crawford hopes to reach a broader audience by offering a new way to absorb the data through music, which Morrison said could be effective. An audience can process the pitch of notes and how they change "in the fraction of the time it takes someone to say something," he said.

"Being able to convey that pure data in a different form and converting it to sound I think can have a big effect" on audiences, Crawford said. "When we treat art and science as two separate things, we're really just lying to ourselves in a way because rationality and how we feel emotionally are part of what it means to be a human."

For a video of musicians playing Crawford's composition, see http://bit.ly/CCCrawford.

By **JoAnna Wendel,** Staff Writer

James N. Pitts Jr. (1921–2014)

UCI

James N. Pitts Jr.

Longtime AGU member James "Jim" N. Pitts Jr. passed away peacefully at his home in Irvine, Calif., on 19 June 2014.

Jim was once described by a colleague as having "parallel processors but serial output," an apt description for those who had the privilege of being part of his scientific and personal lives. He was bursting with such energy and so many ideas at times that how fast he could speak became the rate-determining step in transmission. One could not be around him and avoid getting caught up in his enthusiasm for life and all things in it.

A number of Jim's colleagues from around the globe told him that they learned the basics and more from his book *Photochemisty*, which is still considered a classic.

Early Life and the War Effort

Jim was born in Salt Lake City, Utah, on 10 January 1921. His parents moved to Los Angeles when he was 6 months old, which gave rise to his saying he was from Los Angeles "within experimental error."

He started as an undergraduate at the University of California, Los Angeles (UCLA), in 1939, where he carried out gas photochemistry research with Professor Francis Blacet, an experience that shaped his career. After the bombing of Pearl Harbor, a civilian Chemical Corps was created, and Professor Blacet, along with many other scientific leaders, was tapped to leave his academic position to help develop and test gas masks that would be effective if chemical warfare were used on Allied troops. When Professor Blacet asked Jim to join this effort, he took a leave of absence from UCLA, returning to complete his B.S. in chemistry in 1945 and his Ph.D. in 1949.

His remarkable experiences are described in "The Past as Prologue: An Interview with James N. Pitts, Jr.," published by the Bowling Green State University Center for Photochemical Sciences (*Spectrum, 20*(1), 2007; see http://bit.ly/Spectrum2007), and in an interview published by the American Meteorological Society (see http://bit.ly/Pitts2007). Both are fascinating accounts of what scientists did during the war.

Professor of Chemistry

Jim joined the Department of Chemistry at Northwestern University in 1949. Despite his great appreciation for the department, he could not resist the draw of returning to California in 1954 as part of the founding faculty of a new University of California campus at Riverside (UCR).

He fulfilled many roles at UCR as he rose through the ranks to full professor, such as mentoring generations of graduate students, postdocs, and undergraduates, including Richard Schrock, who went on to win the Nobel Prize in Chemistry.

Jim continued his research in fundamental photochemistry, coauthoring a book on the subject with colleague Jack Calvert. A number of Jim's colleagues from around the globe told him that they learned the basics and more from his book *Photochemisty*, which is still considered a classic.

A Focus on Air Pollution

In the early 1960s, Jim became intrigued with the photochemistry of air pollution, which had become a serious problem for Los Angeles. He cofounded the University of California Statewide Air Pollution Research Center (SAPRC), which was located at UCR, and was its director from 1970 until his retirement in 1988. In reality, he never retired from science, and he continued working on air pollution issues for the rest of his life. He was welcomed as a researcher and mentor at the University of California, Irvine (UCI) in 1994.

Few areas of atmospheric chemistry today escaped his influence. He was author or coauthor of 380 peer-reviewed publications and four books: one on photochemistry, two on atmospheric chemistry, and one directed at helping graduate students navigate the path to obtaining a Ph.D. He was designated in 2001 by the Institute for Scientific Information (now the Thompson-Reuters Web of Science) as one of the "most highly cited researchers."

These statistics do not properly represent his impact, however. He opened up many new areas in atmospheric chemistry, such as reactions of polycyclic aromatic hydrocarbons, which before that point had been definitively stated not to react in air. Jim showed not only that they did react but that toxicity often increased as a result.

The Consummate Mentor

During his career, he mentored several generations of new scientists, many of whom are current leaders in the field, including a number of women in an era when there were few in science. He was always encouraging and supportive—and never short of advice!

Because he was a tennis player, duck hunter, and fly fisherman, his advice was often couched in terms such as "Keep your eye on the ball," "Don't flock shoot," and "Try floating the dry fly past." "Keep moving so they can't draw a bead on you!" was another phrase he often used to inspire those around him to always move ahead.

He generously shared research ideas with students and junior faculty at UCI and helped them write more convincing papers. A dedicated teacher, he continued lecturing to the general public until late in his life, telling fascinating stories about the history of air pollution research and policy.

Recognition for Improving Air Quality

Jim was deeply dedicated to translating the science of air pollution for policy makers and regulators, giving testimony many times before state legislative and congressional committees. As proof of the regard in which he was held, a number of policy makers, including governors Ronald Reagan and Edmund "Jerry" Brown Jr., presidential candidates George McGovern and Edmund Muskie, and Rep. Jerry Lewis (R-Calif.) visited SAPRC to seek his advice.

Jim was most proud of his work with the California Air Resources Board (CARB) as a scientist, informal adviser, and chair of a number of CARB committees. His prime concern was public health and the application of fundamental science to understanding the atmospheric chemistry that affects people. That California has led the way in developing scientifically based control strategies is in no small part due to Jim's efforts.

His awards included those not only for his science (e.g., fellow of the American Association for the Advancement of Science and a number of American Chemical Society awards, including the Tolman Medal) but also for his contributions to improving air quality (e.g., from CARB, the Coalition for Clean Air, the South Coast Air Management District, and the California Lung Association).

An Enduring Legacy

Jim is survived by his wife of 38 years, three daughters, six grandchildren, and their families. He was always very appreciative of an undergraduate scholarship at UCLA, and as a fitting memorial, a scholarship for undergraduate chemistry students has been set up in his name at UCI.

Jim's World War II involvement, his contributions to better understanding the science driving atmospheric pollution, and his total commitment to his immediate family and those of us fortunate to feel like part of his extended family were Jim's proudest accomplishments. The world is a better place for having had him in it.

By **Donald R. Blake, Barbara J. Finlayson-Pitts,** and **Sergey Nizkorodov,** University of California, Irvine; email: bjfinlay@uci.edu

Better Utilization of Marine Seismic Data

Increasing the Access to and the Relevance of Marine Seismic Data;
San Francisco, California, 11–13 December 2014

LDEO

Among other priorities, participants at a recent workshop brainstormed ways to enhance the utilization of the ship's capabilities, including broadening the base of potential users.

Against a backdrop of increasing fiscal challenges to ocean sciences infrastructure, academic, industry, and government representatives of the marine seismic data community met in San Francisco on 11–13 December, just prior to the AGU Fall Meeting.

Among the items discussed were successful examples of academic use of the marine industry's seismic data, strategies to acquire new data from joint industry-government-academic partnerships, the potential for a revised operational model for the University National Oceanographic Laboratory System's R/V *Marcus G. Langseth*, exploration of more efficient use of national and non-U.S. seismic databases, codification of access to industry sources of seismic data, and links to the National Science Foundation's EarthCube initiative. Discussions on the latter sought to specifically identify current limitations to marine seismic research in terms of data management, processing, analysis, and visualization.

Action Items

Discussions were lively and productive, despite a citywide power failure on the first day! Action items from the workshop, which the conveners hope to pursue with follow-on EarthCube Research Coordination Network funding, include

- developing a road map outlining a joint industry project to analyze shallow geomorphology using "nonsensitive" (i.e., upper 1 second) industry, two-dimensional/three-dimensional (2-D/3-D) seismics in the Mississippi Canyon, Gulf of Mexico,
- scheduling EarthCube presentations on seismic imaging, particularly in relation to important science drivers and challenges, at selected professional society meetings in 2015,
- developing increased interoperability between both public domain and industry seismic databases,
- expanding (i.e., with reduced receiver spacing) long-offset ocean bottom seismometer seismic refraction collection,
- encouraging independent testing of seismic source arrays to evaluate marine wildlife impact, and
- considering bringing students on board industry seismic vessels for training purposes.

Charting a Course for the *Marcus G. Langseth*

Workshop participants, many of whom had collected data on *Langseth*, identified the following action items for invigorating utilization of this national seismic imaging resource:

- Develop a regional planning model for *Langseth*, perhaps partly through soliciting periodic letters of intent.
- Provide guidance for international collaborators who need assistance for planning and executing a cruise.
- Provide science consulting, via *Langseth*'s Scientific Oversight Committee (MLSOC), particularly for new users. MLSOC should also poll the relevant community to find out which of the ship's acquisition tools (e.g., sound source, hydrophone receiving arrays) are most important.
- Improve advertising of the spectacular data the ship collects, particularly in three dimensions.
- Endorse training cruises and reserve sailing space for early-career scientists.

> Participants agreed that future databases will need facilitated access to industry seismic information.

A Vision for the Future

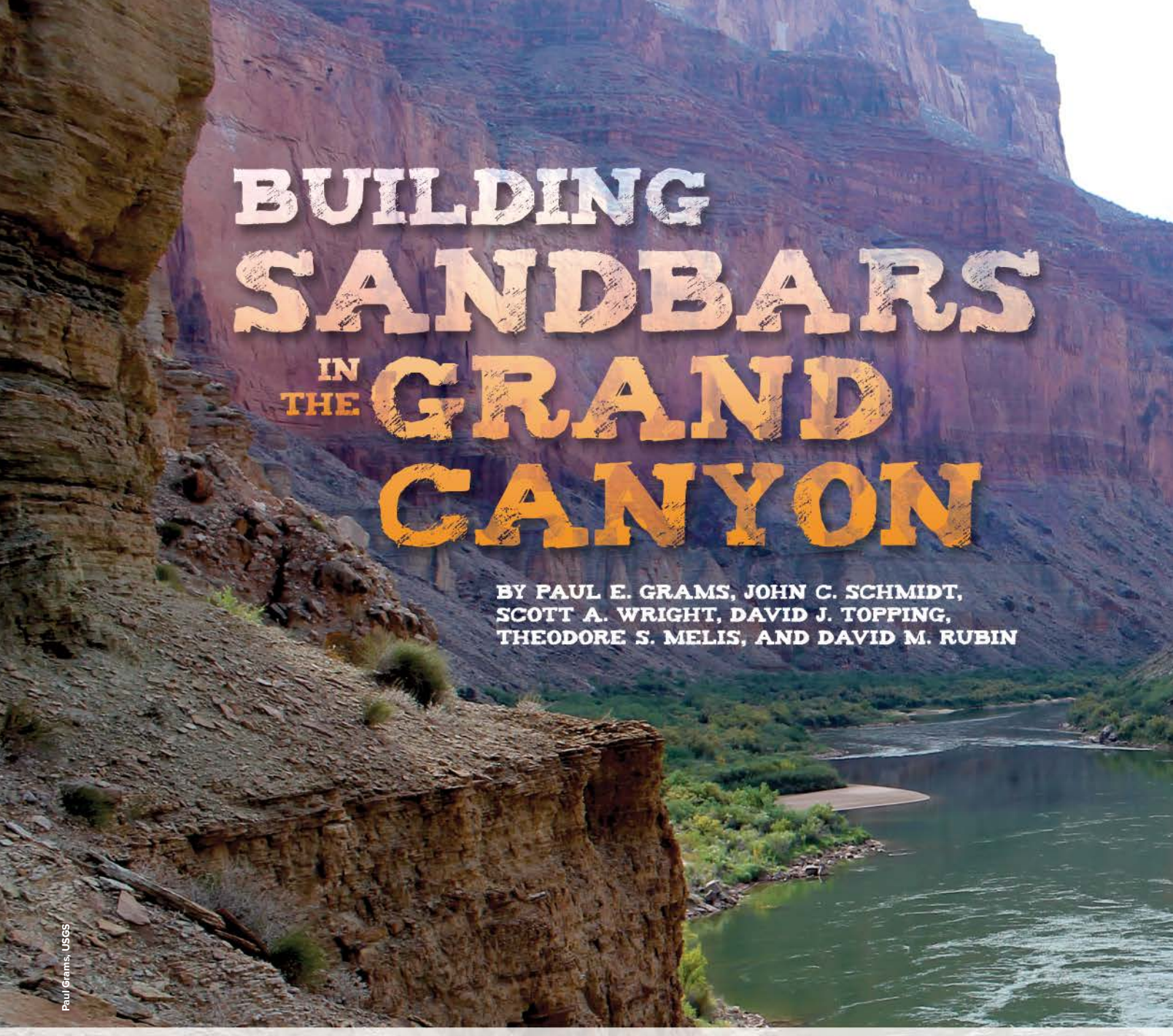
Meeting attendees envisioned future access to marine seismic data from various sources—national and international government agencies, academia, and industry—and that such data will be made more readily available by way of databases envisioned and developed in association with EarthCube.

Participants agreed that future databases will need facilitated access to industry seismic information, joint government-industry-academic collaborations to acquire new data, and a continuing commitment to collect high-quality seismic images in unexplored or poorly explored regions of the Earth (e.g., the Arctic). The *Langseth* currently provides such superb, crustal-scale 2-D and 3-D seismic images, serving a critical role for accessing such data by its user community.

By **James A. Austin Jr.** and **Nathan Bangs,** Institute for Geophysics, Jackson School of Geosciences, University of Texas at Austin, Austin; email: jamie@utig.ig.utexas.edu; and **Dale S. Sawyer,** The Weiss School of Natural Sciences, Rice University, Houston, Texas

BUILDING SANDBARS IN THE GRAND CANYON

BY PAUL E. GRAMS, JOHN C. SCHMIDT, SCOTT A. WRIGHT, DAVID J. TOPPING, THEODORE S. MELIS, AND DAVID M. RUBIN



Paul Grams, USGS

In 1963, the U.S. Department of the Interior's Bureau of Reclamation finished building Glen Canyon Dam on the Colorado River in northern Arizona, 25 kilometers upstream from Grand Canyon National Park. The dam impounded 300 kilometers of the Colorado River, creating Lake Powell, the nation's second largest reservoir.

By 1974, scientists found that the downstream river's alluvial sandbars were eroding because the reservoir trapped the fine sediment that replenished the deposits during annual floods. These sandbars are important structures for many kinds of life in and along the river.

Now, by implementing a new strategy that calls for repeated releases of large volumes of water from the dam, the U.S. Department of the Interior (DOI) seeks to increase the size and number of these sandbars. Three years into the "high-flow experiment" (HFE) protocol [*U.S. Department of the Interior,* 2012], the releases appear to be achieving the desired effect. Many sandbars have increased in size following each controlled flood, and the cumulative results of the first three releases suggest that sandbar declines may be reversed if controlled floods can be implemented frequently enough.

Harnessing the Water and Sediment of the Colorado River

The 220-meter-high and 480-meter-wide Glen Canyon Dam has dramatically altered the 425-kilometer segment of the Colorado River that runs from the dam to Lake Mead, the nation's largest reservoir, at the western end of Grand Canyon National Park (Figure 1). Within the Grand Canyon, and especially its upstream end, known as Marble Canyon, the dam has eliminated fine sediment once supplied from the upstream Colorado River basin, decreased peak flow volumes and magnitudes, increased low-flow magnitudes, and caused daily discharge fluctuations that generate hydroelectric power.

Collectively, these changes reduce both the size and number of the river's sandbars [*Dolan et al.,* 1974]. Sandbars, which

occur primarily in eddies downstream from rapids, provide flat ground for camping and for backwater habitat used by native and introduced fish. They also support vegetation and supply fresh sand to dune fields that bury and protect important archaeological sites.

In 1996, scientists started experiments to learn how best to rebuild eroded sandbars. Many of these experiments involved releasing controlled floods through the hydroelectric turbines and facilities that bypass water around the turbines. These releases, known as HFEs, are about half the magnitude of the average predam spring flood and last 3 to 8 days, which nevertheless amounts to 2 to 3 times the amount of water normally released from the dam over a given period of time.

Flood Science

The first controlled flood occurred in 1996. This release demonstrated that sandbars grow rapidly during the first few days of a flood and that much of the deposition is eroded within 6 to 12 months by normal dam operations [*Webb et al.*, 1999]. The most important scientific finding of the 1996 flood was that sand supplied to the Colorado River by tributaries experienced short residence times, as evidenced by declining sand concentrations during the release [*Rubin et al.*, 2002]. These findings revealed the importance of timing controlled floods to occur shortly after flash floods from major tributaries deliver sand to the Colorado River.

Scientists and resource managers tested this paradigm by releasing controlled floods in 2004 and 2008 after seasonal thunderstorms triggered a series of large sand inputs via tributaries. These floods elevated suspended sand concentrations in the Colorado River and deposited large eddy sandbars.

The evidence from these experiments indicated that releases timed to follow sand inputs, as suggested by *Rubin et al.* [2002], are, in fact, an effective sandbar-building strategy [*Schmidt and Grams*, 2011].

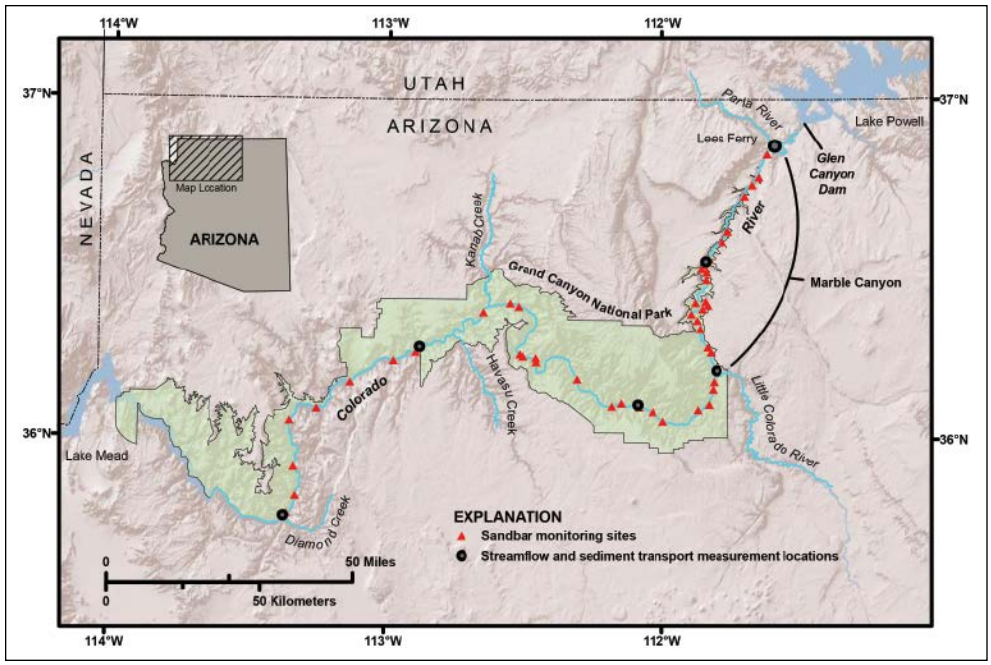


Fig. 1. Map of the Colorado River between Glen Canyon Dam and Lake Mead, Ariz., showing sandbar and streamflow monitoring sites.

Toward a Flood Protocol

Insights gained from the 1996, 2004, and 2008 controlled floods [*Schmidt and Grams,* 2011] and from scientists' understanding of the river's sand budget [*Wright et al.,* 2008] allowed scientists and resource managers to develop the current HFE protocol. DOI now schedules controlled floods depending on sand accumulation in Marble Canyon, the 100-kilometer river segment downstream from the Paria River. This river is the first and most important sand-contributing tributary downstream from Glen Canyon Dam.

Scientists compute sand accumulation as the difference between tributary sand input and sand export from Marble Canyon. Using this computation, resource managers aim to release controlled floods to redistribute the accumulated sand from the bed of the river to sandbars along the banks.

Although the protocol is conceptually simple, implementing it involves several science and policy challenges:

- tracking sand influx from tributaries and transport downstream by the Colorado River
- computing in-channel sand storage
- predicting sand flux for potential controlled floods
- scheduling potential controlled floods in a way that does not disrupt regional water supply and hydropower demands
- evaluating the effects of each controlled flood before triggering the next one

Wright and Kennedy [2011] proposed a strategy to meet these challenges by coupling field measurements with stream flow and sediment routing models. The protocol roughly follows this strategy.

Timing Floods to Maximize Bar Building

To time controlled floods for maximum sandbar-building effect, U.S. Geological Survey scientists continuously monitor sand flux at the downstream end of Marble Canyon using acoustic instruments calibrated to conventional sampling of suspended sediment [*Griffiths et al.,* 2012]. Scientists also make initial estimates of sand inputs from Paria River floods within 24 hours of each event using a model based on observed correlations among discharge, sand concentration, and sand grain size [*Topping,* 1997].

Scientists adjust model estimates and reduce uncertainty by measuring sand concentrations and particle sizes in water samples collected in the field. They use this combined modeling-sampling approach because sand concentrations in the Paria River are too high for other techniques, such as acoustics, to work reliably. The data and tools that implement the model to compute Paria River sand inputs are available to water managers, stakeholders, and the public (see http://bit.ly/sandinput).

As the sediment input season progresses, engineers from the Bureau of Reclamation use the sand routing model of *Wright et al.* [2010] to predict sand export from Marble Canyon for different possible controlled flood scenarios. Scientists have calibrated and verified this empirical model specifically for Marble Canyon on the basis of water discharge and sediment grain size.

The modeling process is iterated to identify when, how much, and for how long water must be released in a controlled flood to export approximately the same amount of sand as was supplied by tributaries during the input season. The goals of this strategy are to build sandbars by mobilizing the recently accumulated sand and to avoid eroding older sand deposits.

Dam operators then schedule the release of a controlled flood from Glen Canyon Dam to match the flow magnitude and duration identified in the modeling process.

Evaluating Floods

Scientists and managers use a combination of photographs and repeat topographic surveys to evaluate the short- and long-term effects of the controlled floods on sandbars. A network of remote time-lapse cameras at 43 sites distributed throughout Grand Canyon captures daily changes in sandbars that show the immediate effects of each controlled flood (see http://www.gcmrc.gov/sandbar/).

Scientists also use the photographs to semiquantitatively categorize sandbars into groupings of sites that show deposition, erosion, or no significant change. They provide these data to managers shortly after each release.

Researchers survey the topography at many of the same study sites annually to quantitatively estimate trends in sandbar area and volume [*Hazel et al.,* 2010]. Thus, the topographic surveys provide precise measures of sandbar response, and the photographic monitoring provides timely data before and after every controlled flood.

Limiting the Flow

The Colorado River ecosystem downstream of Glen Canyon Dam is not the only resource relying on Lake Powell's water. The dam produces a significant amount of hydroelectric power, and releasing long-duration, large-magnitude floods could affect the capacity to generate power later.

DOI caps the controlled flood volume at the maximum flow rate that can be attained with all of Glen Canyon Dam's power plant turbines and the full capacity of the dam's bypass tubes (1274 cubic meters per second). DOI also caps the duration of releases greater than power plant capacity (~890 cubic meters per second) at 96 hours to limit the loss of potential future power generation associated with bypassing water around the turbines.

With sufficient sediment, higher releases would likely build larger sandbars, but such releases would require using emergency spillways and are outside the scope of the HFE protocol. Whenever river managers implement controlled floods, they also reduce reservoir releases in other months to keep the annual volume of water released from Lake Powell consistent with the agreements established among the users of Colorado River water. Controlled floods can be released following either summer/fall or winter sand-supplying floods in tributaries.

Testing the Protocol

In the period from July to October 2012, just 3 months after DOI adopted its HFE protocol, Paria River floods delivered 690,000 ± 117,000 metric tons of sand to the Colorado River. In October, managers made a preliminary estimate of that sand flux and used it in the sand routing model to develop and schedule a controlled flood (see Figure 2). Paria River sand inputs in 2013 and 2014 were 2.8 and 1.8 times larger, respectively, than those in 2012, allowing managers to release additional controlled floods.

Sand inputs were more than enough to support the release of the maximum discharge and duration allowed under the protocol, but operators could not release more than 1050 cubic meters per second because some turbines were shut down for maintenance. Because these infrastructure issues limited the maximum release, these controlled floods exported from Marble Canyon less than 60% of the sand delivered in 2012 and less than 30% of the amount of sand delivered in 2013 and 2014. In each case, the *Wright et al.* [2010] model has been a valuable tool for managers because it has provided a rational basis for designing controlled floods that make efficient use of the sand supplied by tributaries.

Time-lapse images showed that at least half the monitored sandbars increased in size following each controlled flood (Figure 3). However, the response of downstream sandbars to floods does not seem to vary systematically, consistent with observations from previous controlled floods [*Hazel et al.,* 2010]. Researchers think that the amount of sand individual sandbars accumulate varies as a function of local velocities in eddies, which themselves vary due to differences in channel morphology [*Grams et al.,* 2013].

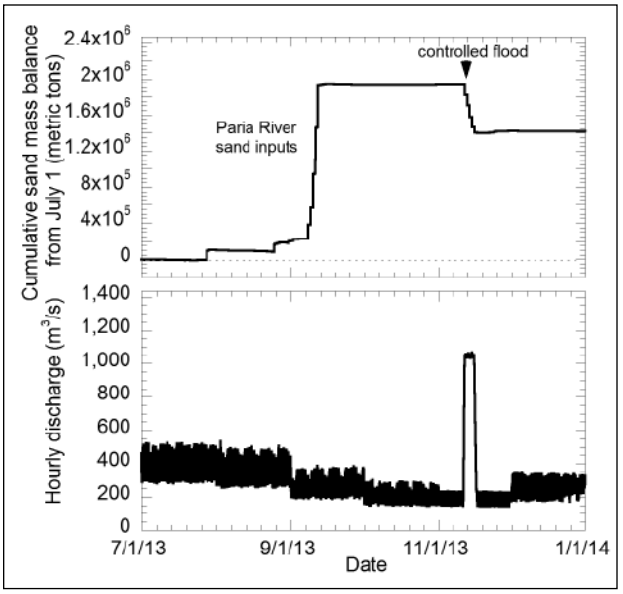


Fig. 2. Sand budget for the 2012 sediment accumulation period and controlled flood in November. The graphs show (top) the observed cumulative sand mass balance for the Colorado River between Lees Ferry, Ariz., and the confluence with the Little Colorado River, 98 kilometers downstream, and (bottom) observed streamflow of the Colorado River at Lees Ferry. Floods from the Paria River caused sand accumulation between July and October. The controlled flood exported approximately 58% of the accumulated sand from Marble Canyon.

Although resource managers have not yet established quantitative goals for sandbar rebuilding, they consider the 2012–2014 results encouraging.

The Colorado River's Uncertain Future

The success of these initial controlled floods does not guarantee that sandbars will continue to grow. Sandbars erode between each controlled flood. Thus, the long-term effects

Fig. 3. Photographs showing deposition caused by the November 2012 controlled flood. The sandbar is 105 kilometers downstream from Lees Ferry, and the view is looking downstream. These and additional photographs depicting the results of the recent controlled floods can be viewed at http://www.gcmrc.gov/sandbar/.

of the HFE protocol depend on how Colorado River runoff, operational decisions about releases from Lake Powell, and seasonal precipitation in the Paria River and other tributary watersheds affect the ability of dam operators to continue implementing controlled floods. Future sediment inflows from tributaries are highly uncertain because they depend heavily on flash floods triggered by rainfall associated with intense seasonal thunderstorms, which deliver a large fraction of the Southwest's rain.

Current climate change models cannot reliably predict how seasonal thunderstorm activity will change in the future. A succession of high-snowpack years or operational decisions to transfer water storage from Lake Powell to Lake Mead could also result in large releases of clear water that typically cause sandbar erosion; indeed, such releases occurred from 1996 to 2000 [*Mueller et al.,* 2014] and in 2011. In these conditions, sufficient sand accumulation to trigger controlled floods is unlikely.

However, almost all climate change projections predict increases in temperature and decreases in Colorado River runoff [*Vano et al.,* 2014]. With recent annual releases equal to or lower than releases from 2000 to 2010, the HFE protocol is likely to increase sandbar size and allow more sand to be retained in Marble Canyon, as anticipated by *Wright et al.* [2008].

Balancing Goals

In this uncertain future, balancing ecosystem goals with growing needs for water and power will continue to be a challenge for society. The HFE protocol is one approach to meet some of those challenges.

Through the incorporation of scientific research, technological advances in monitoring capabilities, and the best available models, scientists and resource managers have developed a strategy that is both flexible and coupled with ecosystem drivers such as runoff and sediment delivery. Although long-term success cannot be predicted, the early results of HFE attempts to maintain the Grand Canyon's sandbars show promise.

Acknowledgments

U.S. Geological Survey sediment transport and sandbar monitoring in the Grand Canyon is supported by the Glen Canyon Dam Adaptive Management Program administered by the U.S. Department of the Interior Bureau of Reclamation. The authors acknowledge the contributions of the many scientists, field technicians, and river guides who have dedicated themselves to the study of the Colorado River in the Grand Canyon. Robert Tusso and Joseph E. Hazel Jr. assisted with analysis of photographs and sandbar data.

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New Insights from Seafloor Mapping of a Hawaiian Marine Monument

By Christopher Kelley, John R. Smith, Joyce Miller, Jonathan Tree, Brian Boston, Michael Garcia, Garret Ito, Jeremey Taylor, Frances Lichowski, Daniel Wagner, Jason Leonard, Belinda Dechnik, and Daniel Leurs

On 15 June 2006, when U.S. President George W. Bush signed the proclamation creating the Papahānaumokuākea Marine National Monument (PMNM), he probably wasn't thinking about underwater morphology. To fully understand the coral reefs and marine ecosystems that the monument was created to protect, however, scientists need to have a detailed picture of the seafloor features, home to corals and other species, as well as the geologic history of the area.

Thanks to a recent, multi-institution expedition, such a picture now exists for the previously sparsely mapped northern half of the monument (see Figure 1). Our team discovered new seafloor features that will not only inform conservation efforts but also enable geologists and geophysicists to revise their understanding of Hawaii's complex geologic past.

Specifically, data should help scientists answer fundamental questions about the area's regional geology. For instance, which seamounts were truly formed because of Hawaiian hotspot volcanism, and which seamounts were not?

A Little-Known Sanctuary

PMNM comprises all the atolls and banks of the Hawaiian Archipelago northwest of the islands of Kaua`i and Ni`ihau. Encompassing a vast 366,631-square-kilometer area—roughly 85% the size of California—it is one of the world's largest marine sanctuaries.

Because of the monument's remoteness and enormous size, marine geologists knew relatively little about the details of its seafloor topography prior to the expedition. As late as 2013, scientists had mapped less than half of the monument's seafloor, mostly in the easier to reach southern half.

A Mapping Campaign

To increase our understanding of the geologic history and deepwater habitats present in the sparsely mapped northern half of the monument, our team of researchers from five collaborating institutions—University of Hawaii, U.S National Oceanic and Atmospheric Administration (NOAA) Pacific Islands Benthic Habitat Mapping Center, PMNM, University of Sydney, and NOAA Observer Program—embarked, during spring 2014, on a 36-day cruise on the Schmidt Ocean Institute's R/V *Falkor*. Using multibeam sonar systems, we collected topographic and backscatter data over a 61,000-square-kilometer area, along

Iridogorgia magnaspiralis, ***the tallest deep sea coral in the world discovered to date, found in the Papahānaumokuākea Marine National Monument (PMNM). The coral in the photo is about 5 meters tall.***

NOAA-HURL Archives

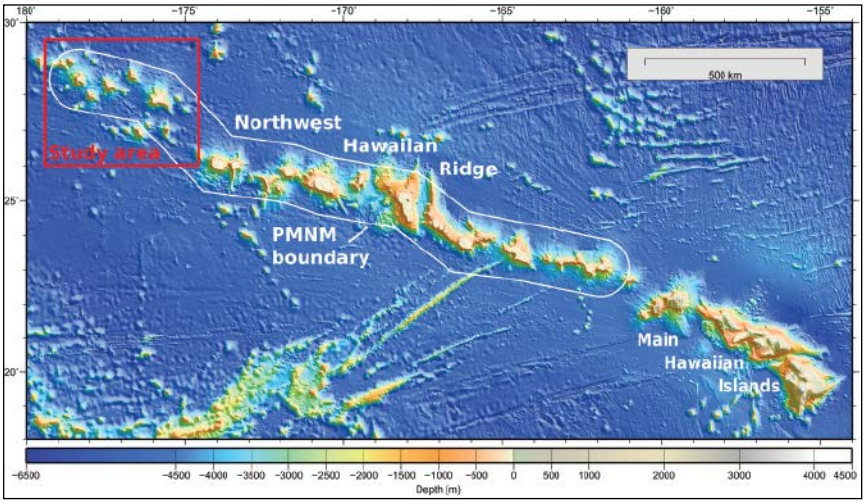

Fig. 1. Global topography of the main and northwestern Hawaiian Islands. The Papahānaumokuākea Marine National Monument (PMNM) boundary is in white; the location of the study site is in red.

with nearly 18,000 kilometers of continuous gravimetric data.

Our data reveal fascinating new geologic details about the monument's seafloor features. Among other findings, our surveys provide, for the first time, complete high-resolution data for all 19 seamounts in this part of the monument. We also fill in gaps in the existing coverage of the Kure, Midway, and Pearl and Hermes atolls.

Challenging Assumptions

Previous radiometric age dating of dredged lavas indicated that four seamounts (Ladd, Nero, Academician Berg, and Turnif) and two atolls (Midway and Pearl and Hermes) are of Hawaiian origin, meaning that they formed 20–30 million years ago (see Figure 2). Analysis of lavas dredged from three other seamounts (Wentworth, an unnamed seamount east of Salmon Bank, and Bank 9) indicated that these originated during the Cretaceous, 82–92 million years ago [*Clague and Dalrymple,* 1975; *Garcia et al.,* 1987; *O'Connor et al.,* 2013].

Pringle and Dalrymple [1993] suggested that these latter three could be part of a so-called Wentworth chain extending south from Hess Rise. Our new survey data support their conclusion and further reveal that this part of the PMNM may contain as many as 15 Cretaceous seamounts. These Cretaceous seamounts have not been covered by Hawaiian volcanism and, as a result, may be more exposed at this end of the chain. Thus, when taken together, the seamounts in this area may have a more complex intersection of old and new features than previously thought.

Furthermore, our data reveal the unnamed seamount east of Salmon Bank (EoSB in Figure 2) to be a guyot, or underwater plateau, with discernible terraces that we think mark submerged ancient shorelines at 1640–1450 meters below sea level. These are up to 1000 meters deeper than the deepest terrace on Nero, the closest Hawaiian seamount. Because terraces that formed at the same time are expected to subside at the same rate (i.e., be at the same depth), the difference in depths supports our hypothesis that the terraces on these two features formed at different times and are unrelated.

Data from the cruise also reveal two other deep guyots. The first is an unnamed seamount east of Pearl and Hermes (EPH in Figure 2) that has a single summit terrace at 1380 meters below sea level. The second is Gambia Shoals, which was known to be a seamount but not a guyot—it has three terraces between 1755 and 1700 meters below sea level. Prior to our cruise, the presence of guyots in the monument was unknown.

Revealing New Features

We discovered that the deep southern part of Bank 9 has three deep terraces between 1450 and 1332 meters below sea level. A previous research group dredged this southern flank and found it to be Cretaceous in age (~82 million years old [see *O'Connor et al.,* 2013]). In contrast, the adjoining northern flank has a summit terrace at 117 meters below sea level and no corresponding deeper terraces matching those found to the south (Figure 3).

This morphology suggests that Bank 9 is a composite seamount created when a Hawaiian volcano erupted just north of a Cretaceous seamount already present on the seafloor.

This is an exciting insight, given that if Bank 9 were truly a Cretaceous seamount, Hawaiian volcanism would have had to halt its eruptive activity, a feat that would be difficult to explain.

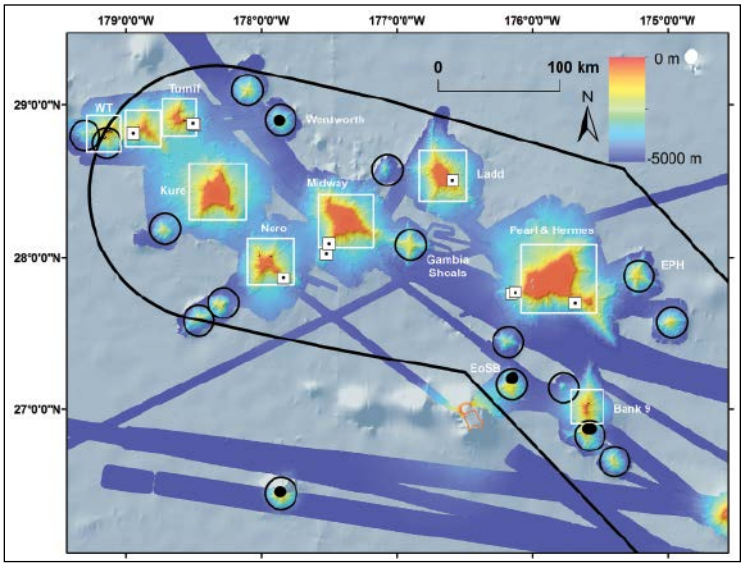

Fig. 2. Locations of features on the newly mapped northern end of PMNM. Black circles are confirmed or inferred Cretaceous seamounts (~82–92 million years old), white rectangles are confirmed or inferred Hawaiian seamounts, black dots are dredged samples dated to Cretaceous ages, and white squares with dots are dredged samples dated to 20–30 million years old.

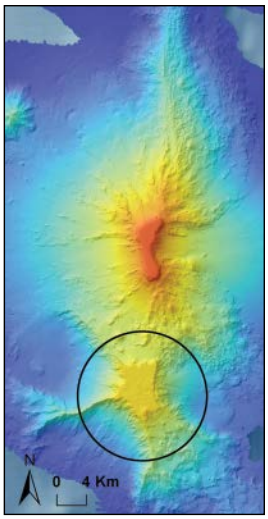

Fig. 3. Bathymetry of Bank 9. The black circle indicates the part that we confirmed is Cretaceous in origin.

Another unnamed seamount west of Turnif (WT in Figure 2) has characteristics that suggest a similar composite seamount. It has a deep southern terrace at 1100 meters below sea level that appears to be the partially buried summit of yet another deep guyot. Similar to Bank 9, it has no corresponding terraces on the northern flank, where the summit reaches a depth of 263 meters below sea level.

The other deep seamounts in this area are conical, indicating that they have never reached the ocean surface. We interpret their relatively smaller sizes and greater depths, which are similar to those of other known Cetaceous seamounts in the region, as evidence of Cretaceous origin. Of these, Wentworth is the only one in the monument that has been dredged by research vessels; data from dredge samples suggest that lavas at the seamount's surface erupted 71–85 million years ago [*Pringle and Dalrymple,* 1993].

Remaining Questions

We will need to do further sampling and analysis to confirm the ages of the rest of the deep guyots and other conical seamounts as well as to track how the Pacific Plate moved over the past 100 million years. As a start, we are examining our new gravity data to distinguish seamounts that formed in the Cretaceous on young seafloor from Hawaiian seamounts that formed on older seafloor and are supported regionally by bending of the seafloor crust.

In preliminary analyses of the new gravity data, some of these deep seamounts appear to have gravity anomalies consistent with features of Cretaceous origin.

Further sampling may happen within the next few months. This summer, NOAA's R/V *Okeanos Explorer* is scheduled to work in the PMNM and will broadcast live video from its remotely operated vehicle over the Internet. Intended dive sites include two of the deep guyots as well as Bank 9.

Seeking Habitats

Exploratory mapping expeditions such as ours provide high-resolution imagery that reveals complex morphological features, such as ancient reef terraces and rift zone ridges. Most of the seamounts we mapped have well-formed rift zone ridges that may serve as habitats for deep-sea corals and sponges. In addition, flank failure scarps—places that have slid off the volcanic flanks along faults—are quite common and may also serve as habitats for deep-sea corals and sponges.

We also defined three previously unknown deep guyots, identified two potential composite seamounts, and advanced scientists' understanding of the complex interaction of the upper northern Hawaiian Ridge with the preexisting Cretaceous seamount chain.

Without data like these, scientists might misinterpret radiometric analyses of rock dredges and fail to discover new potential habitats for important deep-sea species.

As with so many ecosystems, the first step toward conservation is knowing what's there. Our data provide a quantum leap in that direction.

Data are freely available at the Marine Geoscience Data System website (see http://bit.ly/MGDSHawaii).

Daniel Wagner

Team members on watch stand in the R/V Falkor*'s science control lab, where the monitors display real-time multibeam, magnetometer, and gravimeter data streams. Watch standers are responsible for monitoring and logging the quality of the incoming data, communicating with the bridge if course and speed adjustments are warranted, transmitting data to the processing computers in the adjoining room, and conducting sound velocity profiles.*

Acknowledgments

We thank the Schmidt Ocean Institute for the *Falkor* ship days, PMNM for additional funding to support salaries, and the National Science Foundation for grant EAR-1423686 to G. Ito for student support and the lease of the gravimeter from Woods Hole Oceanographic Institution.

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Climate Ride: Are You Up for the Challenge?

Climate Ride

Participants in the fall 2014 Northeast Climate Ride, who rode from New York to Washington, D. C., pose in front of the U.S. Capitol.

For the second year, AGU is participating in Climate Ride! Climate Ride is a nonprofit organization that offers 5-day, staff-supported bike rides or hikes through beautiful areas of the United States to increase awareness for sustainability and raise money for organizations working on issues related to climate change, sustainability, and other environmental causes.

By taking part in one of the rides, participants not only challenge themselves physically but also have the opportunity to network with like-minded peers and meet bright minds in policy, advocacy, and innovation.

AGU's president-elect, Eric Davidson, participated in last year's Northeast Climate Ride, pedaling more than 500 kilometers from New York City to Washington, D. C. This year, Davidson decided not only to pedal for the planet again but to lead the AGU team on the 2015 Northeast ride from Bar Harbor to Boston. AGU caught up with him to ask how he got involved in Climate Ride, what's driving him to participate again this year, and what advice he can offer others who want to join his team—or lead an AGU team of their own!

AGU: *What about Climate Ride appealed to you?*

Davidson: It was suggested to me by a colleague as a schoolkids' challenge—"you think you can do this?" I had never been a big bicycling enthusiast; I rode my bike to work and back every day, 5 miles [8 kilometers] each way, but never took long trips. Climate Ride sounded like a new and interesting challenge. And the fact that the ride is well supported—somebody's taking care of you to make sure you have a hot shower and a good meal and a bed to lie down in and making sure the trail is well marked and there are bike mechanics to help you if you break down—makes it an easy way to get started.

It's also an opportunity to merge together fundraising for your favorite charity or nonprofit and drawing attention to climate change, this important topic of our time.

I also like the idea of getting scientists engaged with the people who are passionate about climate change—it's an opportunity for scientists to learn what's motivating people and to learn how we can communicate our information in ways that make sense to them—and it's a chance for nonscientists to hear from us and talk with us.

AGU: *What was it like riding on the Northeast Ride?*

Davidson: We met people of all ages—there was a high-school kid and some people who were retired. There were people who sailed ahead and finished in a third or half the time of everyone else and people who took their sweet time and took all day. It really was a wide-ranging group. Some people needed to take a day off and ride in the wagon for a day, and that was accepted…there was no rivalry of any sort.

And the landscape was gorgeous. I've mostly driven down the New Jersey turnpike—I hadn't really gone on back roads through Amish country in Pennsylvania and horse country in Maryland, and it was really gorgeous. It was interesting in Amish country seeing the juxtaposition of a solar panel farm mixed in with all the Amish homes. You could spot the Amish homes because we went through on a Monday and that's apparently wash day—the clotheslines were full of a week's clothes hung out to dry in the sun—that's a different kind of solar power.

AGU: *Were you worried about how to meet the $2800 minimum fundraising goal? What were some tactics you used or saw others use?*

Davidson: It was easier than I expected. I simply put a tag on the bottom of my emails saying "Please support me" and put on the URL where they [recipients] could get the information. I was surprised by how many people really were pleased to learn about what I was doing and how to support me. I had pledges ranging from $15 to one of $300. But even the $15 pledges add up, so I was able to exceed my goal.

A lot of people are reluctant as adults to ask their friends and family to support them, but actually, a lot of people *do* want to support and encourage their friends and colleagues in various ways. So I think as much as it seems unnatural for many people, if they can imagine themselves on the giving side, then they shouldn't feel so bad about being on the asking side.

AGU: *How did you train for the ride?*

Davidson: Assuming that most potential riders have day gigs like I do, I suggest getting out every weekend that time and weather permit and doing at least 20–30 miles—40–50 if you can—and then midweek, if you have opportunities, even if it's only a 5- or 10-mile ride to the store or to work. Just be on that bike as often as you can and try to get in a couple of long rides if you can.

It'll be another fun, rewarding way to spend a few days seeing the countryside

AGU: *What made you decide to participate again this year/lead a team from AGU?*

Davidson: The fact that I had a great experience and a lot of fun and it was a good challenge where I felt a sense of accomplishment at the end—that was a good thing to want to repeat. There's also novelty in a different route, seeing a different part of the countryside. I've gone from Bar Harbor to Boston before, but I'm sure I've never gone on these back roads, so it'll be another fun, rewarding way to spend a few days seeing the countryside. Last year I got involved in this before I had any inkling that I'd be nominated to run for president-elect of AGU, but now that I'm in that position and AGU has embraced this as a vehicle for its members to get engaged, I'm happy to help encourage an AGU team to develop.

AGU: *Why donate to AGU?*

Davidson: I think AGU is an appropriate beneficiary because it's the leading scientific organization that is doing the science to understand how humans are changing the climate and what can be done about it. We need good information; society needs good information. AGU's mission is to promote Earth and space science for the benefit of humanity, and I truly believe that AGU does a good job of promoting that goal and that our scientists are producing the science that's needed to understand and convey what we do and don't know about climate change and the challenge it poses to humanity. And AGU provides a service to its members to enable them to do their science and get their information out there to the scientific community and the general public.

AGU: *Anything else to add for people thinking of doing this (and those who might still be a little hesitant)?*

Davidson: If an old man like me can do it, they can do it. It puts you a little outside your comfort zone; there were times going up those hills in southeastern Pennsylvania when I wondered what the heck I was doing, but once you got to the top of the hill or at the end of the day, there was such a great feeling of accomplishment—it's worth it to push yourself beyond your comfort zone.

For people having doubts: I want to emphasize that this is a great way to ease yourself into a longer ride than you would have done otherwise because it's so well supported. The staff are so positive and encouraging and take care of your needs—they're there as fallback if you have mechanical problems or you need to ride in a car for a little while—so if you're ever thinking about wanting to try something like this, this is a comfy and easy way to do it—about as comfy and easy as you're going to find.

By **Olivia Ambrogio,** Sharing Science Program Manager, AGU; email: oambrogio@agu.org

Join the AGU team on the 2015 Northeast Climate Ride, 17–21 September, from Bar Harbor to Boston. Climate Ride offers several other bike rides and hikes across the United States. Visit http://sites.agu.org/climate-ride/ to learn more about Climate Ride, the rides and hikes offered, and how you can ride for AGU.

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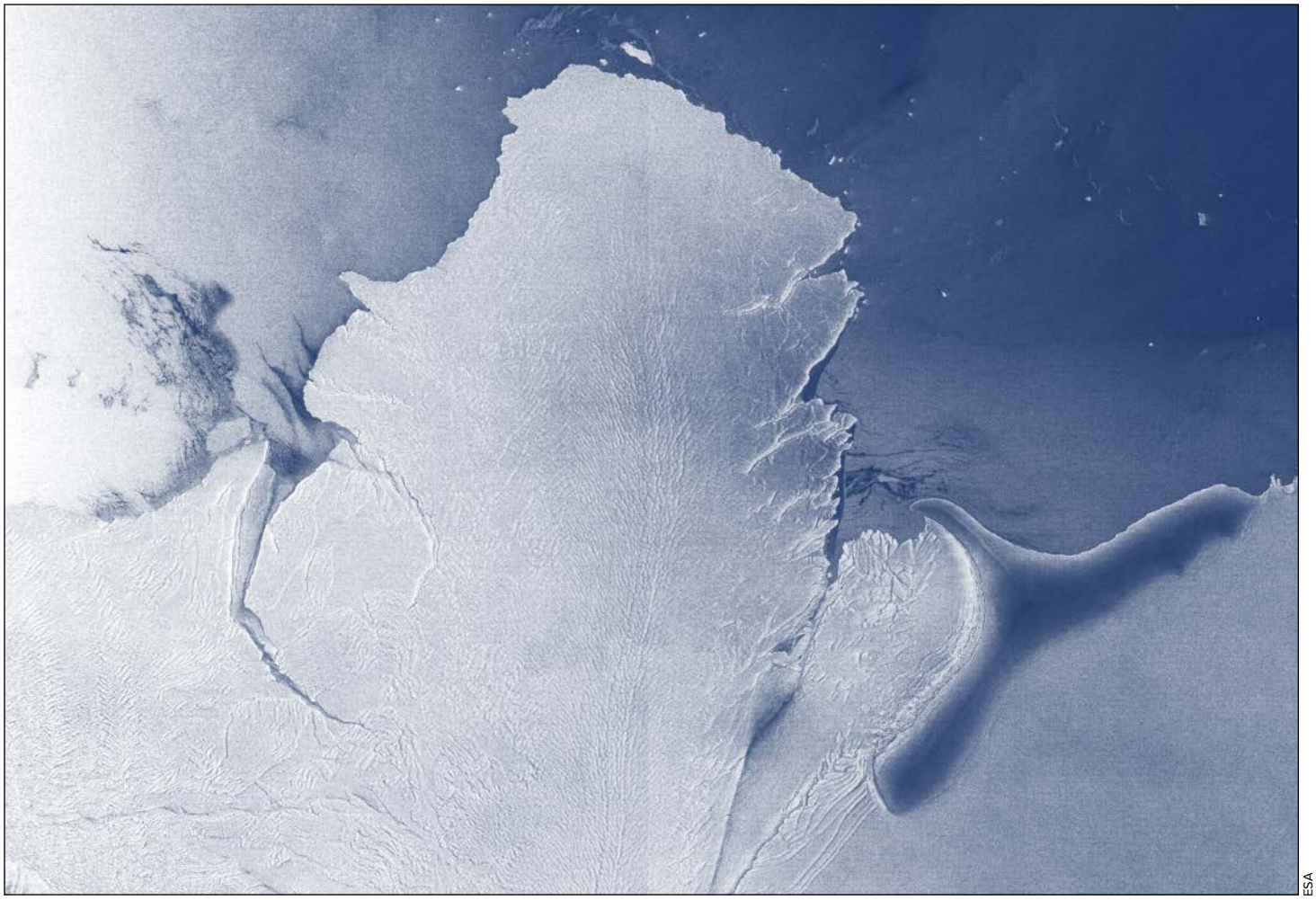
Researchers Track Moving Ice Shelves to Estimate Antarctic Ice Loss



ESA

An Envisat radar image from 5 March 2011 shows the Stancomb-Wills Ice Tongue protruding from Antarctica's Brunt Ice Shelf. As satellite data become more ample, movement on ice shelves may help scientists track ice loss from the interior of Antarctica.

Recent studies have shown that large parts of the Antarctic Ice Sheet may be imperiled by the loss of vast ice shelves that abut the continent and slow the flow of ice into the sea. These ice shelves float on seawater, which melts them from below, but this process has proved difficult to observe and quantify. Instead, most efforts employ an indirect approach: Satellite data are used to track changes in the surface elevation at fixed points, and then all other contributing factors are subtracted out, leaving behind only the effects of basal melting.

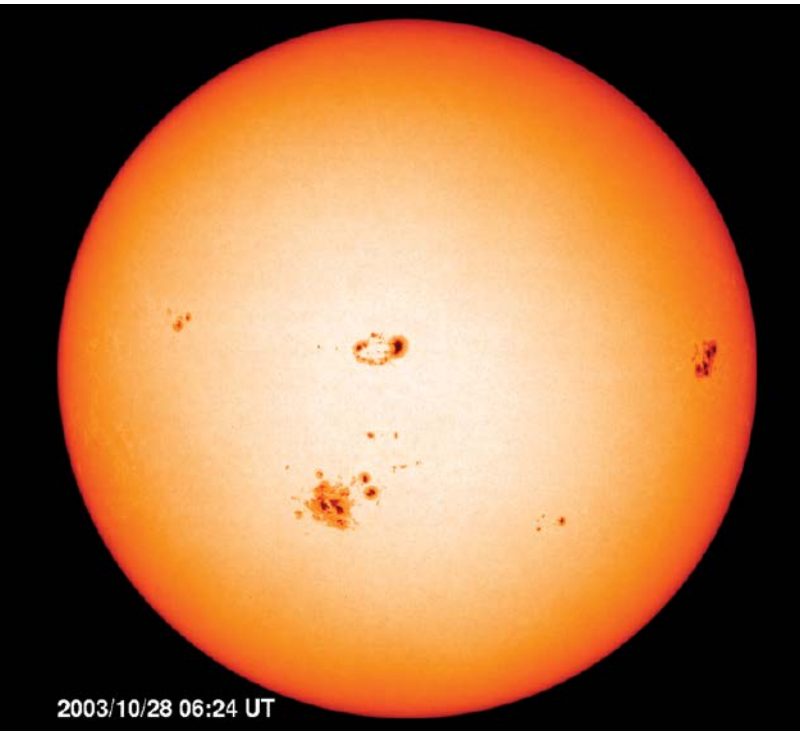
Moholdt et al. propose an improvement on this technique—they tracked elevation changes at the same spots on the moving ice shelf rather than fixed geographic coordinates. This approach removes the effect of changes in elevation caused by motion of the rough ice surface. The researchers demonstrated that their approach reduced the noise in estimates of surface elevation changes by about half and improved calculations of basal melt rates. The main limitation of their approach is that it requires ample satellite data, which is not presently available at all locations of interest.

The researchers used this approach to estimate basal melting for the two largest Antarctic ice shelves, the Ross and Filchner-Ronne, for the period between 2003 and 2009. They found that the Ross Ice Shelf lost about 50 gigatons of ice per year and the Filchner-Ronne lost about 125 but that these losses were approximately compensated by snowfall and ice dynamics, leading to steady state conditions for both ice shelves.

The main uncertainty in their calculations arose from the rate of compaction of snow as it turned into ice, which affects surface elevation but can be hard to accurately estimate. The researchers propose using compaction rates for nearby ice that is grounded on bedrock and does not experience changes due to basal melting. (*Journal of Geophysical Research: Earth Surface,* doi:10.1002/2014JF003171, 2014)

—Julia Rosen, Freelance Writer

What Causes Sunspot Pairs?



NASA/SOHO

What causes sunspot pairs, such as the ones seen in the center of the image above, to form?

Among the many scientific mysteries involving the Sun, scientists are still puzzled about the origins of sunspots: large regions of an extremely strong magnetic field that appear on the Sun's surface. In 1981, a scientist observed that sunspots, which are generally seen in pairs, preferentially appear at the boundaries of unipolar magnetic (UM) regions—regions on the surface of the Sun that have rather weak magnetic networks of one polarity.

Akasofu offers evidence in support of this observation using solar magnetograms—"pictures" of the magnetic fields on the Sun's surface. The author notes that there are many single spots (not in pairs) that cannot be explained by the present ideas on the formation of pairs of spots, which involve magnetic flux tubes rising from below the photosphere. He found that single spots of positive polarity tend to appear in a positive UM region, and single spots of negative polarity tend to appear in a negative UM region.

Using the above facts, a pair of spots can be explained if a positive single spot forms at the boundary of a positive UM region and induces a negative single spot in an adjacent negative UM region across the UM boundary.

The research shows that UM regions and their boundaries are essential in forming sunspot pairs and helps to better predict where on the solar disk sunspots will occur. The author also notes that because the incidence of sunspots is directly related to solar activity, UM regions may heavily influence space weather and the Sun-Earth connection. (*Geophysical Research Letters,* doi:10.1002/2014GL060319, 2014) **—JoAnna Wendel, Staff Writer**

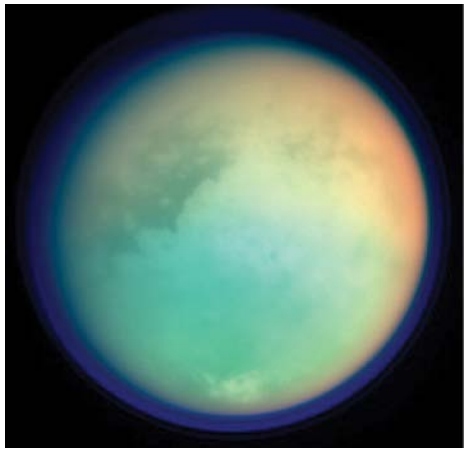
When the Sun Goes Quiet, Titan Gets Gassy

Saturn's moon Titan is the only moon in the solar system that has an atmosphere as thick as Earth's, consisting of more than 98% nitrogen, roughly 1.4% methane, and smaller amounts of other gases. NASA's Cassini satellite has been circling Saturn since 2004, witnessing more than one-third of its 29-year orbit around the Sun, allowing it to observe the changing of the seasons. However, a new study finds that the seasons are not the only thing changing Titan's atmosphere: Its chemical makeup fluctuates according to the Sun's 11-year cycle of magnetic activity.

Westlake et al. analyzed data from 41 flybys of Titan, some at altitudes of less than 1000 kilometers when Cassini dipped into the upper fringes of its atmosphere. The authors found that the amount of methane there varied wildly over time—it dipped from mid-2006 to 2008, then gradually recovered for 2 years but crashed to roughly half of its 2006 peak by 2011.

These fluctuations correspond neatly to the 11-year solar cycle, in which the Sun's rotation gradually winds up magnetic field into contorted coils, giving rise to flares and sunspots that emit ultraviolet and X-ray light. Upon reaching Titan, this powerful radiation can tear methane molecules apart.

After reviewing the Cassini data, the authors think that this destruction of methane occurred from 2006 to 2008 during the last phases of the previous solar maximum. Upon reaching solar minimum in 2008, the quiet Sun allowed Titan's methane to recover its levels. Then, as the Sun once again began gearing up toward its most recent solar maximum in 2013, methane levels declined. This case is bolstered by data from the last mission to make such measurements—the Voyager 1 spacecraft, which swooped by Titan in 1980 during solar maximum conditions and found similarly depleted levels of methane.



NASA/JPL/SSI

Saturn's moon Titan and its hazy atmosphere, seen in ultraviolet and infrared wavelengths using data from the Cassini orbiter.

By using one- and three-dimensional models, the authors were also able to trace the movements of the different chemicals through Titan's atmosphere. During solar maximum, the broken-down methane remnants combine to form heavier hydrocarbons that rain down through the atmosphere. During solar minimum, the replenishment of methane in Titan's upper atmosphere comes from its lower layers. Although it takes only weeks for increased solar radiation to send Titan's methane levels crashing, it takes years for them to recover. The authors predict methane levels will not reach their previous peak until sometime this year. (*Journal of Geophysical Research: Space Physics,* doi:10.1002/2014JA020394, 2014) **—Mark Zastrow, Freelance Writer**

New Insights into the Formation of Old Norwegian Mountains

The Western Gneiss Region of Norway's Caledonide Mountains offers a rare window into the formation of the old mountain chain. The region is rich in eclogites: coarse-grained rocks, often laced with pink and green minerals, that form at high temperatures and pressures. Because of the extreme conditions necessary for their creation, they are mostly found deep within Earth.

The eclogites in the Western Gneiss Region are thought to have formed by a process called ultrahigh-pressure metamorphism (UHPM) that often occurs when continents collide.

Previous research has taken advantage of their presence in the Caledonides, dating the metamorphic rocks using radiogenic isotopes to determine that high-pressure processes may have begun in the region as early as 430 million years ago and ended approximately 30 million years later.

The most precise dates were found by measuring lead—produced from the decay of uranium—within the mineral zircon, which is common, albeit in low abundance, within eclogite. However, the authors point out that zircon in eclogite is stable over a large range of pressures and temperatures, so it may not serve as a reliable signal of shifts in pressure.

In a new study, *Kylander-Clark and Hacker* sought to pin down the end of the multimillion-year mountain-building process without relying on zircons from eclogites. The authors instead turned to zircons within igneous rocks likely formed under low pressure as eclogite metamorphism ceased. They took 21 samples of igneous rock that intruded layers of ultrahigh-pressure rock and found Caledonian zircon present in about half of those.

Andrew Kylander-Clark

High-pressure, dense and strong eclogite (dark blocks), carried back to the surface from mantle depths by weaker, buoyant deeply subducted crust. Light-colored melts that cut these rocks were emplaced after eclogite rose from mantle depths.

To be sure the rocks formed after the UHPM period had ended, the researchers used mass spectrometry to peer into the contents of the rocks. Armed with the knowledge that igneous zircon formed under low pressure has higher heavy rare earth element concentrations than when the mineral forms under high pressure, the authors were able to infer when the zircon crystallized.

All the samples the researchers analyzed had higher concentrations of the rare elements, indicating that they did, indeed, form under low pressure. Upon dating the igneous rock samples, they found that UHPM may have ended as early as 406 million years ago in parts of the Western Gneiss Region. (*Tectonics,* doi:10.1002/2014TC003582, 2014)

—Shannon Palus, Freelance Writer

Could Amazonian Deforestation Increase Cloudiness and Rain?

Deforestation is believed to cause drier and warmer conditions because of a decrease in tree cover. However, a counterintuitive effect of increase in cloudiness and rain due to deforestation has been found by *Khanna and Medvigy* in Rondônia, a state in west central Brazil, which was once covered by more than 50 million acres of Amazonian rainforests, half of which has been replaced by pasture.

Jagubal, CC BY-NC-ND 2.0 (http://bit.ly/ccbyncnd2-0)

As deforestation continues in the Amazon rainforest, scientists find that vegetation height can affect precipitation patterns.

The authors provide evidence that differences in vegetation height can influence cloudiness: Large patches of short pasture interspersed between large patches of tall trees give rise to different amounts of cloud cover because of faster wind speeds in the cleared areas.

The researchers investigated this atmospheric effect of deforestation in Rondônia using the recently developed Ocean-Land-Atmosphere Model. They modeled the cleared area, covered by grass approximately 30 centimeters tall, sandwiched between evergreen forests roughly 30 meters tall. This introduces a smooth landscape between tall rough forests and results in a speeding up of surface winds over the pasture.

This faster wind rises and forms clouds as it encounters an undisturbed forest patch. Conversely, a suppression of clouds is observed when the slow wind blowing over forests encounters a smooth patch of pasture. This response to variations in vegetation height gives rise to enhanced cloudiness in the downwind half of deforested regions and reduced cloudiness in the upwind half.

The authors also found that this effect of contemporary deforestation dominated other atmospheric effects of deforestation—such as thermal triggering of clouds found by previous studies. Thus, the findings also imply that an increase in deforestation will broadly shift the regional precipitation regime. If these results can be applied to other rainforests, they may help researchers glean some insight into the large-scale atmospheric impacts of deforestation around the world. (*Journal of Geophysical Research: Atmospheres,* doi:10.1002/2014JD022278, 2014) **—Shannon Palus, Freelance Writer**

Regional Nuclear War Could Cause a Global Famine

Erick Pleitez, CC BY 2.0 (http://bit.ly/ccby2-0)

Fires from regional nuclear war could release enough soot into the atmosphere to severely affect agricultural output across the globe.

Nuclear winter has captured the collective imagination of the world since the uneasy days of the Cold War between the United States and the Soviet Union. In this hypothetical climate scenario, smoke from the fires ignited by nuclear explosions blocks out the Sun, leaving the Earth's surface dark, cold, and dry and the Earth's inhabitants at the mercy of a global famine. Today, nuclear weapons are no longer the prerogative of a few select countries; a detonation of less than 1% of the global nuclear arsenal could alter climate at a scale and pace that are unprecedented, even for the Anthropocene.

To find out what effect those potential changes could have on China—the largest producer of grains in the world—*Xia et al.* used three climate model simulations that mimicked the effect of 100 atomic bomb explosions starting fires that release 5 teragrams of soot into the atmosphere above India and Pakistan. For comparison, the explosive power of these detonations is less than 0.03% of that of the global nuclear arsenal.

The models predicted changes in the air temperature, precipitation patterns, and the amount of solar radiation that reaches the Earth's surface. The researchers applied those climate simulations to crop models to simulate crop production at 51 locations across China during a 10-year cold period following this "small" nuclear war.

The simulations demonstrated that a regional nuclear conflict between India and Pakistan—or any conflict that infused the upper atmosphere with at least 5 teragrams of soot—could result in lower yields of rice, maize, and wheat at most of the locations across China. The authors conclude that reduction in agricultural production would have a profound impact on the more than 1 billion people living in poverty in the world.

Given that any climatic changes that affect crop production in China are likely to impact agriculture in countries at similar latitudes, including the United States, the authors speculate that a regional nuclear war could lead to a global famine. (*Earth's Future,* doi:10.1002/2014EF000283, 2015) **—Kate Wheeling, Freelance Writer**

AGU's Career Center is the main resource for recruitment advertising. All Positions Available and additional job postings can be viewed at **https://eos.org/jobs-support**.

AGU offers printed recruitment advertising in *Eos* to reinforce your online job visibility and your brand.
Contact advertising@agu.org for more information about reserving an online job posting with a printed *Eos* recruitment advertisement.

- To view all employment display ad sizes, visit **http://sites.agu.org/media-kits/files/2014/12/ Eos- Employment-Advertising.pdf**
- *Eos* is published semi-monthly on the 1st and 15th of every month. Deadlines for ads in each issue are published at **http://sites.agu.org/media-kits/eos-advertising-deadlines/.**
- *Eos* accepts employment and open position advertisements from governments, individuals, organizations, and academic institutions. We reserve the right to accept or reject ads at our discretion.
- *Eos* is not responsible for typographical errors.
- Print only recruitment ads will only be allowed for those whose requirements include that positions must be advertised in a printed/paper medium.

Atmospheric Sciences

HPC Application & Workflow Positions

Princeton University's Cooperative Institute for Climate Science has a number of openings in the general area of high-performance computing, algorithms and workflows. The positions will support an exciting new initiative to adapt GFDL/CICS Earth System models to novel architectures and systems.

Our effort will take place in the context of an integrated effort to target NOAA Earth system models to these novel architectures, where we will contribute to the overall NOAA effort, as well as specifically target models and model components used in GFDL Earth System Modeling and based on the Flexible Modeling System (FMS). (http://www.gfdl.noaa.gov/fms).

The scope of the work is broad: it includes

- redesigning the architecture of the Earth system model for greater concurrency
- the optimization of codes for fine-grained parallel architecture, requiring knowledge of compilers (including layers like LLVM) and languages for expressing parallelism (MPI, OpenMP, OpenACC, CUDA, PGAS)
- the redesign and substitution of existing algorithms with others better suited for novel architectures.
- the redesign of the complete workflow systems for maximizing system throughput

Candidates will join a dynamic team of computational experts attached to one of the foremost research institutions in Earth system science, will collaborate with top scientists and algorithm developers in the field, and will have access to an extraordinary range of computational and data resources. This is a growth area for the lab and the lab's group leading this effort, and candidates will have considerable leeway to develop their own ideas within the context of the lab's mission. Candidates must be able to work in a team environment that combines the collegiality of an academic setting with the focus of a mission agency, and be able to deliver rigorously tested results to meet deliverables for international collaborative science missions. Occasional travel to project meetings, site visits, and national and international conferences and workshops is to be expected.

Candidates must possess an MS in a relevant field (computer science, or physical sciences) and at least two years experience working with weather or climate codes and runtime environments in an HPC context. At least one senior hire (PhD, and/or 10 years relevant experience) is envisioned. Knowledge of one or more parallel programming methods is desirable. Appointments will be made at either the Associate Professional Specialist or Professional Specialist rank, depending on the candidate's credentials.

Applicants must apply online to http://jobs.princeton.edu, Requisition #1500296 and submit a CV, publication list and contact information for at least 3 references.

Princeton University is an equal opportunity employer and all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, disability status, protected veteran status, or any other characteristic protected by law. This position is subject to the University's background check policy.

Program Director–National Suborbital Education and Research Center

The National Suborbital Education and Research Center (NSERC) seeks a Program Director to provide leadership in science mission operations support to meet the research, education, and technology needs of the NASA Airborne Science Program and the scientific community. The Program Director will be responsible for science operations support for various aircraft platforms, including the DC-8, P-3B, C-130, Global Hawks, and ER-2s, as well as for interfacing to the scientific community. Duties include mission planning, personnel scheduling, budgeting, logistical support, and supervision of NSERC staff. In addition, the Program Director will be expected to lead the implementation of improvements that will make the various airborne platforms more scientifically valuable. The Program Director will also be responsible for the organization and improvement of training and communications for the Airborne Science Program including the annual NASA Student Airborne Research Program (SARP).

Qualifications include a graduate degree in a natural or physical science, or in engineering. Extensive experience performing and directing research from multiple aircraft platforms is also required. Significant management experience is required including financial and personnel management.The Program Director will be expected to have strong interpersonal and leadership skills, as well as an ability to communicate effectively with a broad spectrum of clientele including NASA Headquarters management. He or she should also demonstrate an ability to collaborate with scientists and aircraft operations personnel. Experience working with students is a requirement and directing student research is highly desirable. A history of success earning external funding will be a plus.

Applicants are required to be eligible for employment under U.S. export control laws and must meet the requirement of being a "U.S. Person" (U.S. citizen, a lawful permanent resident, refugee, or granted asylum) or must be eligible to obtain appropriate U.S. Government authorization for access to export controlled equipment,

technology, or software.UND will not sponsor an applicant for employment authorization for this position. All information collected in this regard will only be used to ensure compliance with U.S. export control laws, and will be used in compliance with all laws prohibiting discrimination on the basis of national origin and other factors.

NSERC is affiliated with the Earth System Science and Policy Department within the John D. Odegard School of Aerospace Sciences at the University of North Dakota (UND). More information is at http://www.nserc.und.edu/. NSERC is funded through a long-term cooperative agreement with NASA with NSERC staff currently based in Colorado, California, and at the University in Grand Forks, ND. The location base for the Director is negotiable. This opening is a twelve-month, non-tenure-track faculty position with the possibility of renewal.

Interested candidates should submit a CV, list of publications, statement of research and education interests, and contact information for three references by August 18, 2015 to: Karen Katrinak, NSERC, UND Earth System Science & Policy Dept., Clifford Hall Rm 300, 4149 University Avenue Stop 9011, Grand Forks, ND 58202-9011; phone (701) 777-2482; fax (701) 777-2940. Applications may be e-mailed to:k.katrinak@nserc.und.edu.

Applicants are invited to provide information regarding their gender, race and/or ethnicity, veteranís status and disability status on the form found at http://und.edu/affirmative-action/apcontrolcard.cfm. This information will remain confidential and separate from your application. Please reference Position Number 23851.

The University of North Dakota is an Affirmative Action/Equal Opportunity Employer. The University of North Dakota encourages applications from women, minorities, veterans, and individuals with disabilities.

The University of North Dakota determines employment eligibility through the E-Verify System.

North Dakota veterans' preference does not apply to this position.

The University of North Dakota complies with the Jeanne Clery Disclosure of Campus Security Policy & Campus Crime Statistics Act. Information about UND campus security and crime statistics can be found at http://und.edu/discover/_files/docs/annual-security-report.pdf.

Hydrology

Director of the Water Institute

The Penn State Institutes of Energy and the Environment (PSIEE), in the Office of the Vice President for Research at The Pennsylvania State University, invites applications for Director of the Water Institute.

The Water Institute is the newest of the institutes under PSIEE. The inaugural Director will be charged with leading the unit in shaping the overall water related research portfolio; in coordination with over 120 exceptional faculty, distributed across eight colleges at University Park and several regional campuses. Current water research activity includes, three major centers supported by NSF and EPA. and over $40 million per year of external funding for water and closely allied research fields. The quality of Penn State`s water scholarship is exceptional; with the fifth most citations and the highest citation per publication ratio of all major U.S. universities during the last five years. Additional information about Penn State's water programs and PSIEE are detailed in the Water Task Force Report and PSIEE Strategic Plan, both available at psiee.psu.edu.

The Director of the Water Institute must have a strong interest in facilitating interdisciplinary water scholarship, developing the Water Institute's grant portfolio, and increasing the exposure of Penn State as a national leader in water research. The Director will also participate in the recruitment of new faculty.

Successful candidates must have a Ph.D., or equivalent credentials appropriate for a tenured or tenure-track professor; as well as an outstanding publication and external funding record in water research. The candidate`s area of research may address any aspect of water science, policy, law, engineering, design, ethics, etc. The tenure home of the Director will be determined in consultation with the successful candidate and the relevant department. As an administrator, the position is subject to yearly goal setting and review, and regular 5 year performance reviews.

To apply, submit a cover letter, curriculum vita, and the names and contact information of at least three references. Applications will be reviewed beginning July 6, 2015 and will be accepted until the position is filled.

Apply to job 57767 at http://apptrkr.com/201523734

CAMPUS SECURITY CRIME STATISTICS: For more about safety at Penn State, and to review the Annual Security Report which contains information about crime statistics and other safety and security matters, please go to http://www.police.psu.edu/clery/ , which will also provide you with detail on how to request a hard copy of the Annual Security Report.

Penn State is an equal opportunity, affirmative action employer, and is committed to providing employment opportunities to all qualified applicants without regard to race, color, religion,

age, sex, sexual orientation, gender identity, national origin, disability or protected veteran status.

Ocean Sciences

Postdoctoral Research Associate Position at the Applied Physics Laboratory of the University of Washington, Seattle, WA.

The Applied Physics Laboratory (APL) at the University of Washington is seeking Post-doctoral Research Associates with research interests in Oceanography, Polar Science, Remote Sensing, Environmental Acoustics and Ocean Engineering.

APL is a unit of the University of Washington and a University Affiliates Research Center of the Navy. Expected terms are two years. Positions are not project specific; a specific applicant is expected to define his/her research goals within the broad program areas of the participating APL departments (Air-Sea Interaction & Remote Sensing (AIRS), Acoustics Department (AD), Ocean Engineering (OE), Ocean Physics Department (OPD), Polar Science Center (PSC). Successful applicants must hold a recent (no more than 4-years) PhD or foreign equivalent in order to assume a post-doctoral position.

A transition to permanent staff following the completion of the post-doc appointment is possible subject to availability of funds and the demonstration of an interest in developing independent research initiatives during the course of the post-doc appointment. Opportunities to collaborate with scientists across the UW campus provide access to a broad range of expertise both during the post-doctoral research and as a permanent member of the staff.

University of Washington faculty engage in teaching, research and service. University of Washington is an affirmative action and equal opportunity employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, age, protected veteran or disabled status, or genetic information.

The position offers salary commensurate with experience and excellent benefits.

Screening of applicants will begin June 16, 2015 and applications should be received prior to June 13, 2015. Finalists will be contacted in July. Travel expenses will be covered to allow finalists to present their recent work in an APL seminar.

Job offers be will made in September 2015 with start dates negotiable between October 2015 and March 2016.

Applicants are asked to submit electronically:

(1) A curriculum vitae,

(2) A publication list,

(3) A brief research proposal (no more than 5 pages, double-spaced, excluding bibliography and figures) describing research to be pursued during a two-year tenure at the University of Washington,

(4) The names of four individuals who can provide a letter of reference.

In addition, a letter of support from a mentor in one of the participating departments (AIRS, AD, OE, OPD, PSC) is strongly encouraged. Further information on current research at APL, by department and principal investigator, can be found at: http://www.apl.washington.edu/departments/departments.php

Applications should be submitted preferably via email to:

Dr. Kevin Williams

Sr. Principal Physicist, Acoustics Department Chair, and Liaison of Science and Engineering Group of APL

Applied Physics Laboratory - University of Washington

1013 NE 40th Street

Box 355640

Seattle, WA 98105-6698

williams@apl.washington.edu

Assistant Professor (Coastal Physical Oceanography) Tenure Track

Department of Oceanography Graduate School of Engineering and Applied Sciences Naval Postgraduate School, Monterey, CA

The Oceanography (OC) Department in the Graduate School of Engineering and Applied Sciences at the Naval Postgraduate School (NPS) invites applications for the position of tenure track Assistant Professor in the field of coastal physical oceanography. We are seeking candidates with core strengths in areas such as: coastal and nearshore processes; field experimentation; and coastal modeling and data assimilation. The successful candidate is expected to develop an externally funded research program that spans basic to applied research areas and involves graduate students. The candidate must have a strong commitment to graduate teaching.

We are seeking a colleague to join our vibrant OC Department, which has a long history of excellence in physical oceanography, ocean acoustics, ocean dynamics, nearshore processes, ocean waves and turbulence, ocean analysis and prediction, and high latitude ocean dynamics. The OC Department has a strong research infrastructure, such as facilities and vessels located in close proximity to Monterey Bay, CA, an experienced group of technical staff, and computational resources. The OC department promotes interdisciplinary research and encourages research collaborations with the number of oceanographic institutions located around the bay. Additional information can be found online at http://nps.edu/Academics/Schools/GSEAS/Departments/Oceanography/index.html

Minimum qualifications:

- Requires an earned doctoral degree in coastal physical oceanography or related field that supports the OC Department's instructional needs
- Evidence of teaching aptitude
- Evidence of potential to advise student theses and dissertations
- Evidence of strong potential for scholarship leading to scholarly publications
- Must currently hold or be eligible for a Secret clearance
- U.S. citizenship preferred

A letter of application including CV, statement of teaching and research interests and philosophy, and the names of three referees should be sent by July 31, 2015 to:

Dr. Jamie MacMahan, Faculty Search Committee Chair

Department of Oceanography

Naval Postgraduate School

Monterey, CA 93943

831-656-2379

jhmacmah@nps.edu

Salary is commensurate with qualifications and experience. Relocation package, including recruitment/relocation incentive may be authorized. The position will remain open until filled.

The Naval Postgraduate School is an equal opportunity employer. For additional information about NPS, please refer to the website at http://www.nps.edu

Post-doctoral position in ocean ensemble prediction

A Post-doctoral research position in oceanography is available at NRL, Stennis Space Center. The objective of this project is to develop a state of the art global ensemble forecast system based on the Navy's operational HYbrid Coordinate Ocean Model (HYCOM) model. The system is expected to provide ocean forecasts and the associated uncertainty estimates that are critical to the US Navy's future missions. The technology to be used is based on the ensemble Kalman filter (EnKF) theory. The ensemble system is expected to be implemented for operation in the future. It will adequately represent the initial state uncertainties and accurately predict the ocean state and probabilistic information up to months. A stochastic

Ocean Dynamics and Prediction Research
Naval Research Laboratory

The Naval Research Laboratory is seeking postdoctoral and senior researchers to push forward the frontiers of ocean forecasting. Problems that must be addressed cover a wide scope of physics including surface waves, thermohaline circulation, ice, nearshore circulation, and ocean/atmosphere coupling from global to nearshore scales. This challenging work includes processing and analysis of satellite and in water observations, construction of numerical model systems and assimilation for predicting the ocean environment. This work is long term, with the goal to provide new technology for systems moving to operational forecast centers.

This is an excellent opportunity to work with some of the best modelers and data analysts in the ocean community. The Naval Research Laboratory has access to the major supercomputer sites as well as excellent local computer resources. The laboratory is collocated with the Naval Oceanographic Office, which is the largest national operational forecast center for oceanography.

For a quick overview of some of the research projects within the NRL Oceanography Division at Stennis Space Center, visit the web site:

http://www7320.nrlssc.navy.mil/projects.php

Applicants must be a US citizen or permanent resident at time of application. Applications will be accepted until positions are filled. Please mail or e-mail a resume and description of research interests, or phone:

Gregg Jacobs
NRL Code 7320
Stennis Space Center, MS 39529

via e-mail: jacobs@nrlssc.navy.mil
Phone: 228-688-4720

University Lectureship in Seismology
UNIVERSITY OF CAMBRIDGE
Department of Earth Sciences

We invite applications from candidates carrying out creative and innovative research in the general area of seismology.

Candidates should have an outstanding record of research in a relevant subject area and will be expected to develop a vigorous research programme at an international level. The person appointed will be expected to contribute to the Department's undergraduate teaching at various levels; at elementary level they may be asked to help with teaching outside their field of specialisation and all academic staff take part in our undergraduate field teaching. We welcome applications from persons with degrees in Earth Sciences, Physics, or Mathematics or allied disciplines.

The successful applicant will be expected to contribute to the research activity of the Department leading to interaction with academic staff across several areas of the subject, to supervise research students and actively to seek external funds to support their research.

Further particulars and information at http://www.jobs.cam.ac.uk/job/6626/ or contact the Administrator (ab78@esc.cam.ac.uk).

forcing model is expected to be developed to account for the model-related uncertainties. This position is full time with a duration of one year initially and can be extended for further years. Applications will be reviewed immediately until the position is filled. Salary and benefits are highly competitive, relocation will be paid. Please email a resume and description of interest to Mozheng Wei (Mozheng.Wei@nrlssc.navy.mil; 228-688-4493).

Supporting Scientist for Surface Water and Ocean Topography (SWOT) Mission

The Jet Propulsion Laboratory (JPL), California Institute of Technology invites applications for a scientist position in support of the NASAís Surface Water and Ocean Topography (SWOT) satellite mission (http://swot.jpl.nasa.gov). The SWOT mission will use high-resolution wide-swath altimetry technology as a means of completely covering the world's oceans and freshwater bodies with repeated elevation measurements. SWOT will revolutionalize our understanding of the oceanic circulation at mesoscales and submesoscales as well as the global dynamics of terrestrial surface waters and their interactions with coastal oceans in estuaries.

The candidate is expected to work under the guidance of the SWOT Project Scientist to provide support on mission-related scientific problems through data analysis, ocean modeling, and data assimilation. Specifically, the candidate is expected to (1) develop a method to produce high-level gridded product, (2) conduct high-resolution ocean general circulation model (OGCM) simulation, (3) perform data assimilation experiments with OGCM and the feasibility of reconstruction of synoptic variability, (4) carry out analysis of simulated SWOT data, and (5) conduct simulation experiments related to AirSWOT.

The successful applicant must have a PhD degree in Oceanography or related scientific or technical discipline; demonstrated working knowledge of the forefront of ocean dynamics, preferably on oceanic mesoscale and submesoscale processes; experience with either ocean general circulation modeling or observational analysis of the above noted processes; peer-reviewed publications in this field. Two years of related experience beyond PhD is highly desired.

Two Postdoctoral Positions at the University of Hawaii

Applications are invited to two Postdoctoral Fellow positions at the International Pacific Research Center, School of Ocean and Earth Science and Technology, University of Hawaii at Manoa, located in Honolulu, Oahu, to work on NASA-funded research projects.

The first project studies the dynamics of anisotropic mesoscale coherent structures and eddy organization in the upper and intermediate ocean.

The second project is to enhance sea surface salinity products from the Aquarius satellite mission and to study salinity signatures of various dynamical features in the ocean.

Candidates should have a recent PhD in ocean sciences or a closely related field. Both jobs will utilize satellite and in situ data as well as outputs of high-resolution numerical models and adequate experience is required along with good programming, communication, and article writing skills.

Postdoctoral Fellows will be working at IPRC with Drs. Nikolai Maximenko and Oleg Melnichenko. Initial appointments are for one year and can be extended for the second year contingent on performance and funding availability.

Interested candidates should send email describing research interests, a curriculum vitae, and a list of three references (with telephone numbers and email address) to: maximenk@hawaii.edu

Please indicate which of the positions is applied for. Positions are open until filled. Applications submitted by July 3, 2015 will receive full consideration.

IPRC is a multi-disciplinary, climate-centered institution with rich history of international collaborations. To learn more, visit http://iprc.soest.hawaii.edu

Solid Earth Geophysics

Geology/Geophysics Scientist

The Jet Propulsion Laboratory (JPL), a Federally-Funded Research and Development Center operated by the California Institute of Technology for NASA, invites applications for a full-time position in geology or geophysics, with an emphasis on spaceborne remote sensing observations. The applicant will join a broad-based team of scientists and engineers to advance JPL's Earth Surface and Interior research that excels in applying space and airborne remote sensing data, in-situ measurements and state of the art models to Earthís surface and mantle processes, including their interactions with other components of the Earth system. The selected applicant will help develop and lead the Laboratoryís Earth Surface and Interior research directions as well as conceive and carry out new remote sensing systems and missions..

The scientific scope of interest for this position is broad and includes land surface processes, tectonics, subsidence, natural hazards, and post-glacial rebound. The technical scope includes forward modeling, inverse methods, relevant field measurements, and interpretation of measurements from ground-based, aircraft and satellite instruments. The selected applicant is expected to participate in or lead science definition and advancement of new science, technology, and mission proposals.

The applicant must have a PhD in Geology, Geophysics, or a related technical discipline along with two years of related experience beyond PhD. The applicant shall have an established reputation along with a broad knowledge of remote sensing measurement approaches and expertise in modeling and interpretation of the data for Earth Surface and Interior science applications.

JPL/Caltech offers a competitive salary and impressive benefits, and provides research opportunities at the leading edge of Earth Surface and Interior science. To view the full job description and apply, visit: http://Careerlaunch.jpl.nasa.gov/ (Job ID #2015-5084). Applications will be reviewed as they are received, and should include a curriculum vitae, a career statement with research objectives, and contact information for three professional references. JPL/Caltech is an equal opportunity/affirmative action employer.

Postcards from the Field

Dear Everyone,

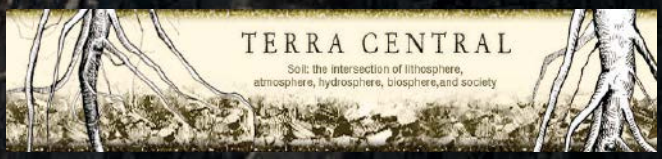
As an economic geologist, I feel like a dwarf from *Lord of the Rings* when I explore underground mines. This photo is from the Porcupine Gold Mine in Ontario, which we visited as part of a field course in the Canadian Abitibi led by Dr. Thomas Monecke with the Colorado School of Mines.

Wish you were here,
Melissa Anderson
Ph.D. student at the University of Ottawa, Canada

View more postcards at
http://americangeophysicalunion.tumblr.com/tagged/postcards-from-the-field.

AGU Blogosphere

Connect to AGU's network of Earth and space science blogs



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blogs.agu.org

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